SCHOOL SCIENCE AND MATHEMATICS

VOL. VII. No. 3 CHICAGO, MARCH, 1907 WHOLE No. 50

PROFIT AND LOSS IN EXPERIMENTAL CHEMISTRY.*

BY LYMAN C. NEWELL, PH.D.,

Professor of Chemistry, Boston University.

The teaching of experimental science involves grave difficulties. It is my purpose in this paper to point out some of the difficulties presented by experimental chemistry and to suggest means for their elimination.

The profit and loss arising from a course in chemistry is by no means limited to the experimental part. Numerous pedagogical difficulties exist in all branches of this science. But it seems prudent to limit the present discussion to the experimental content. The delimitation is made partly from insufficient time to consider the whole field but mainly from a conviction that the problems arising out of the laboratory work are more closely connected with the profit and loss account of teachers and students.

I. The best method of teaching chemistry is undoubtedly the one that includes all avenues of approaching the student's mind—demonstration lecture, informal conference, frequent recitation, text-book study, written and oral tests, varied experiments, and so on.

These pathways, however, are not equally productive. Demonstration lectures please a majority, informal conferences and recitations help a minority, while examinations irritate a plurality. Text-books are complacently studied and believed, but in themselves they yield uncertain results. Real mental work begins when the student enters the laboratory and tries to correlate the concrete facts gleaned in his work-shop with the abstract data read in his study or gathered by his experimentations. And

* Read before the Central Association of Science and Mathematics Teachers, Nov. 03, 1906.

unless he is provided with proper experimental work and conducted judiciously through it, particularly during its early stages, he loses the mental training which such work is designed to provide. Consider the mental equipment of most students who begin chemistry. The study of history and language has occasioned much memorizing and led to a potential store of disconnected facts largely outside the student's daily life and experiences. The mathematics, too often shirked or perfunctorily performed, has exercised the critical faculties but has involved little or no contact with concrete data. The science if studied at all is apt to be so distorted, incomplete, and unrelated that it is positively pernicious in advanced work. My color scheme may be too somber but you may decide for yourselves as to the general correctness of the picture. Consequently when the student begins chemistry he enters a new world. It is unfamiliar and transcends his experience. He is appalled by the language, the apparatus, and the manual operations. He is likewise distracted by facts, things, and unyielding results. He soon discovers, too, that his work is no longer abstract. Day after day he is summoned before the bar of concrete tasks and commanded to observe things, to tell what he sees, and to interpret their meaning. But in his previous work he seldom made accurate observations and he infrequently drew logical deductions. So the first days in the laboratory are irksome, fruitless, or absurd to student and teacher alike. And this inability to observe, think, and conclude with reasonable accuracy may continue indefinitely if not corrected as far as possible at the beginning of the course. Too often the beginner is pushed into a mysterious labyrinth and expected to escape by the time the bell rings for the next period. He may emerge but he cannot tell the method of escape or repeat the adventure.

The error in the early days of laboratory instruction is the failure to construct a bridge between the past experience and the new experience. Connections between the known and the unknown must be built quickly. No subject can be learned unless it is connected with other subjects. And the more numerous and obvious the connections are, the more quickly will the new subject be grasped. The beginner in his new world is not blind but awestruck, not stupid but bewildered, not dumb but uninformed. Therefore the keynote of the early laboratory work

should be simplicity. Substances should be designated by familiar names, apparatus should not be complicated or extensive, nor should the manipulation require much skill or attention. The experiments themselves should yield obvious results, the more attractive and striking, the better. It is a childhood period, when colors, sounds, odors, and other fundamental phenomena are intensely interesting. These early days are not the time for atoms and ions, distracting apparatus, bewildering questions, and recondite conclusions. The first work in all its aspects should be so simple that its performance will not destroy the mental confidence of those who have entered a strange land and begun to labor in unfamiliar fields but will rather entice them into those skillful labors of hand and independent operations of mind which are essential to profitable experimental work. A crude psychological attitude must be tolerated, such as mere curiosity, imperfect visualization, inaccurate observation, faulty deductions, over-valuation of unessential data. As teachers, we should be content with this unpromising attitude of the student, knowing that patience, guidance, toleration, and hope will help him walk from this stormy and troublesome pathway into fruitful and familiar fields.

II. The kind of laboratory course which is most profitable depends upon several factors. Among the important ones are the money available for supplies, general equipment of the laboratory, size of class, future work of the students, place of chemistry in the curriculum, relative time devoted to experiments, and time at the disposal of the teacher. These factors might be discussed with profit, but all are subordinate to one element fundamental in its relations, viz., the kind of experiments performed by the class. A few years ago the pendulum swung toward simple quantitative experiments. Now it seems to be hovering over a course which includes only a few quantitative experiments selected by tradition rather than for their pedagogical value. My views on this point have been somewhat fully expressed in print† and perhaps it would be the wiser plan to omit further reference to this topic. But during the last three or four years new facts have been revealed and old ones have been emphasized, so I venture to discuss these at the risk of taxing your patience.

† *School Science*. Vol. I, No. 1 (March, 1901), page 12.

There are better reasons now for doing simple quantitative experiments than ever before. Inexpensive and reliable balances are available and chemicals of known purity can be purchased at relatively low prices. Moreover the pioneer work has been done. We know that certain experiments can be performed with accuracy by beginners, that some do not yield good results at the hands of elementary workers, and that a few are unsuitable in a laboratory where skill and dispatch are not possessed but are being acquired. Furthermore the use of quantitative experiments by teachers in widely separated localities and working under varied conditions proves the adaptability of such work. Objections have been made to the quantitative experiments which consume considerable time or require expensive apparatus. The objections are valid in many cases, but the difficulty can be overcome by having the teacher perform the experiments at the lecture table or with the class in the laboratory, and require the class to calculate the numerical result. To be sure, the class as a group of individuals loses the opportunity to acquire manipulative skill, but this desideratum can be secured in other ways. Such experiments as the composition of ammonia gas, weight of a liter of oxygen, and composition of air belong to this group. In these experiments the quantitative aspect of the principle is more important than the manipulation. The exact result produces a definite mental impression. Moreover it reveals mistaken or vague notions. Some students never know their shortcomings until confronted with mathematical data derived from tangible evidence.

With large classes it is often necessary to limit the quantitative experiments to those which consume a relatively small amount of time and require simple apparatus. There are many experiments meeting these requirements, e. g., water of crystallization, percentage of oxygen in the air by the pyrogallic acid method, relation of magnesium to oxygen, solubility curves, percentage of carbon dioxide in a carbonate, and equivalents. But it is not sufficient merely to perform these experiments. To be profitable the results must be utilized in the class room to emphasize the underlying principle. This is especially true of equivalents. It is waste of time to find the equivalent of zinc and stop there. Other equivalents should be determined, such as those of aluminium, magnesium, copper, and iron. Equipped

with these values, the teacher can quickly show the relation of equivalents to atomic weights and lay the foundations for a further treatment of atomic weights and valence. Besides, the scaffolding once erected can be strengthened by frequent references to data already established. The fertile field once sown with vital seed cannot be profitably left for other tracts however alluring.

Not all experiments can be quantitative in nature. This kind serves its purpose but it cannot replace those which illustrate and emphasize the properties of substances and their numerous interrelations. A course of experiments to be profitable must not overlook the chemistry of common substances and industrial processes. The value of these descriptive experiments, which usually constitute the larger part of the traditional course, is much enhanced by tabulating results, especially when many substances are used. So also they should be repeated in order to emphasize a new standpoint. A reinterpretation compounds the interest set to the credit of previous experiments. Tests, detection of common properties, oxidation, and reduction come under this classification. There is a danger, too, of limiting the number of experiments, not as to the total but as to the number pertaining to a single topic. Many students, for example, leave their chemistry with a notion that oxygen is obtainable only from a mixture of manganese dioxide and potassium chlorate or hydrogen solely from granulated zinc and dilute sulphuric acid. They need a broader view. It takes only a few minutes for them to learn that oxygen can be liberated from nitrates, chlorates, and oxides, and that strong alkalies as well as acids yield hydrogen. For the last two years I have covered this extension feature of laboratory work by providing extra experiments. The rapid workers perform all the additional experiments, while the slow workers are stimulated to activity by the prospect of increased credit. It is essential also to follow up the laboratory notebooks. Numerous errors creep into records. If these are not indicated, the student fails to distinguish truth from error, indeed in many instances he never realizes his mistakes until attention is called to them. Simple mistakes may be indicated by an interrogation point, omissions by a caret, and serious errors by the word "ask." This last device necessitates a conference which quickly sets the student on the right

track and adds much to the general profit of the laboratory work. Finally a laboratory course loses much of its potential profit if it does not articulate with the class room work. The two should proceed hand in hand. It is rather difficult to keep the pace uniform, however, unless one employs some such device as that mentioned above, viz., maximum and minimum work. The course as a whole must be a unit whatever it costs the teacher in personal comfort and daily labor.

III. Laboratory work to be profitable must be performed under conditions which permit accurate observations, clear thinking, and correct judging. Due attention must be paid to the psychological atmosphere. I have set forth my views on this fundamental topic in a previous paper.‡ After several years of varied labor with many kinds of students I can only reiterate with considerable emphasis the principles already on record. It would be somewhat redundant, however, to discuss the bearing of curiosity, inhibition, interest, and voluntary attention upon laboratory work. Nevertheless certain phases of the psychological problem deserve consideration in the present paper. It is rather trite to say that profitable mental work cannot be done when the brain is tired or compelled to act under fatiguing conditions. But it is true, especially when mental alertness is the prime factor which determines the profit. Some educators think profitable laboratory work can be done at any time, in any place, and under any conditions. These critics point with triumph to the achievements of Berzelius or of Liebig who worked with meager equipment. But the notion is false and harmful. A laboratory of all places should be a room where mental activity can proceed harmoniously and rapidly. Those who have watched a class at work in the laboratory know too well how quickly minds are thrown into confusion. Mental machinery is delicately adjusted. Noise, visitors, too much moving about, needless conversation, and numerous other distractions if allowed to prevail will reduce the profit; indeed there may be no profit, but rather a distinct mental loss. It is perhaps too autocratic to demand absolute quiet in a chemical workshop. Such a Utopian condition is hardly possible in these days of surplus energy. But fatiguing conditions which are unnecessary need not continue, and the sooner they are reduced to a minimum the

‡ *School Science*, Vol. II, No. 9 (March, 1903), page 487.

better it will be for all whose brains are not well poised and under control. This may seem trivial, but trifles count when profits are small. Unsuitable environment will also increase mental fatigue. In this category belong air too highly heated by a perniciously managed ventilating system and air rendered impure by fumes carelessly generated in the laboratory. To these must be added the inconvenient location of supplies, insufficient room to record notes, and lack of comfortable stools. We are apt to overlook the factor of fatigue and err in attributing to stupidity what is mainly due to avoidable environment. An ebbing tide has little or no motive power.

IV. There has been a distinct change in the character of experiments performed by students in the last ten or fifteen years. When laboratory work first began to be general in our high schools and colleges, students were not only told what to do but were minutely informed what would happen. Consequently they lost the mental value of their experiments. Later they were told what to do and then asked questions which mature students would find it difficult to answer. Such beginners likewise lost the profit from laboratory work. Within the last five years or so these psychological blunders have been eliminated to some extent but basal principles are often ignored. Let us as teachers consider the kind of laboratory directions we are justified in setting before our students. There are two pitfalls—the "Do tell" and the "Don't tell." Enough must be told the student to enable him to proceed quickly and sensibly with those operations which will produce a result comprehensible to him. I would hardly say proceed intelligently because he can seldom do so. He knows little or nothing about the course of the phenomena and about the final result. How can he? He is performing an experiment, literally trying something new. Like a man in the woods at night, he knows he is walking in a trodden path but he is not sure what obstruction he will meet or where he will emerge. If perchance the student does know the whole story, then the experiment will not call forth his powers. In any case he must be given directions which at least permit rapid and sensible procedure. Now it is difficult to prepare a set of laboratory directions which are psychologically suitable for all grades of mental development from that in which idiomatic English cannot be interpreted to that in which many words are burdensome. Each year reveals defective phraseology. But the direc-

tions to be of the maximum utility must permit rapid and sensible procedure along a somewhat indistinct pathway. A rather extended experience in preparing laboratory directions has led me to the conclusion that sedulous care should be taken not only to eliminate ambiguity but to use simple sentences, short and adequate. Moreover these directions, to yield their greatest psychological profit, must not be interrupted by irrevelant questions. Such injections switch the brain upon a side track. Thus the directions for preparing oxygen from the usual mixture should not contain questions about the function of the manganese dioxide or the principle underlying the collection of gases over water. These queries may be introduced with propriety at some later place. Nor should directions involving a continuous operation be split asunder by questions about subordinate features of the manipulation. Thus a "why?" cannot with good judgment be inserted in the midst of a request to "introduce part of the water." Similar illustrations need not be cited.

It also seems well established that diagrams and models are indespensable in many cases. Descriptions fail to describe certain operations and many arrangements of apparatus. The eye is quicker than the brain. The use of such pictorial and material aids not only economizes time and facts but serves also to train the student in visualization—a factor in scientific education which yields a high rate of interest.

The mere performance of an experiment, as suggested above, is usually profitless. The student must observe certain phenomena and draw legitimate conclusions if his task is to be fruitful. Here again there are pitfalls. If he is asked simply "What" and "Why" or autocratically told to "Observe and explain," he may observe the essential scientific phenomena and draw a legitimate conclusion therefrom—but he may not. Certain experiments invariably reveal conspicuous facts and permit accurate deductions, but many do not. In this negative or indefinite class it is necessary to suggest the line of observation, such as change in color, evolution of gas, difference in temperature, formation of a precipitate, and so on. The facts need not be told outright. Such a departure from a rational procedure is rarely necessary though it is preferable usually to sacrifice a little infromation for the benefit of a basal mental process. Hints about the desired observations are entirely legitimate, indeed they determine to a considerable extent the rate at which

the student acquires an indispensable trait, viz., accurate observation of essential data.

I presume most students dislike to undertake voluntary thinking. Experiments are usually performed with pleasure, but when the time arrives for drawing conclusions from accumulated data, most students halt, evade, or utterly fail. It is necessary therefore to induce or compel such ultimate thinking by some device. Simple interrogative or imperative sentences are usually used. But these in themselves are not a panacea for the mental inertia exhibited by most students when confronted by an array of facts demanding classification. The student is not entirely to blame for this dilemma. Professor H. P. Talbot of the Massachusetts Institute of Technology recently raised the question as to how far we are justified in demanding conclusions from the experiments which now make up the traditional course in beginners' chemistry. The query is excellent. Do we not in many cases require students to draw conclusions which we as teachers could never draw from the meager data furnished by one or two experiments? I think we have failed to appreciate the situation from the learner's standpoint. We expect the immature beginner to judge as we judge now with our stock of information. We forget our own struggles and blunders and with the assurance characteristic of maturity calmly expect the child to be as wise as the parent.

Teaching, especially experimental science, has suffered too long from the Agassiz idea. In our veneration for a traditional method salutary for investigators we have forgotten that multitudes are not endowed with initiative and insight. It is imperative therefore to provide conditions favorable for this final mental leap which is to carry the student from the confused field of unrelated facts across the ditch of doubt to the firm ground of truth logically derived. Therefore in all cases where the conclusions like the observations are not quite obvious it is insufficient to say merely "Explain," "Why?" "Conclusion?" "What is your answer?"

To comply with these conditions which determine the mental gain or loss, the general nature of the conclusions must be indicated. Thus in the familiar experiment with sodium and water, it is not enough to ask, "What does the experiment prove?" but, "What does this experiment prove about the composition of water?" It is not always possible to select the most fruitful

question. Individuals differ widely in their capacity to reason, but fully 90 per cent of beginners need suggestions to enable them to derive valid and appropriate conclusions from the scanty data furnished by their experiments.

V. The profit and loss in experimental chemistry is doubtless largely determined by the establishment of points of contact between the old world and the new world of the student, by the use of a judiciously balanced course of experiments and by the incorporation of the psychological principles of mental fatigue, concepts, and suggestion. But these factors, however valuable, are insufficient without a fourth, viz., the attitude of the teacher. He must be a personal supervisor. In his hands rests the key which locks or unlocks the door of the student's mind. Imbued with the spirit of science and filled with a sympathy for youth he can inspire his students with a love for truth. But if he is impelled to labor by mercenary motives or filled with contempt for those who are toiling up the heights of knowledge, he may turn an experience essential to mental growth into a profitless task. No laboratory can run itself, and no teacher is influential enough to conduct courses *in absentia*. A small amount of teacher cannot transform a large amount of student. There is no such thing as pedagogical catalysis. The greatest teachers the world has ever seen lived with their students. In his "Life and Experiences" Roscoe writes this of Bunsen, his teacher: "This constant presence of the master, this participation of him in the work of the persons both young and old, bore in on the minds of all the lesson that it is the personal and daily contact with the leader which creates a successful school; and that whilst fine buildings and well equipped laboratories are good things in their way, they are as tinsel and dross, unless accompanied by the devotion and collaboration of the teacher." And Roscoe himself believed and practiced the principles of his teacher, for he says elsewhere: "The personal and individual attention of the professor is the true secret of success; it is absolutely essential that he should know and take an interest in the work of every man in his laboratory, whether at the beginning or at the finish of his course." The rise and development of the French chemistry was partly due to the personal attention bestowed upon students by Morveau, Fourcroy, Vauquelin and their immediate successors. And the commanding power of German chemists today began in Liebig's laboratory many years

ago. Some one may say this personal supervision is well enough in colleges where research is in progress, but it is hardly necessary with high school pupils. Indeed there is a strong tendency to let youth develop without restraint and supervision, it being argued that he gains experience thereby, that he needs to know failure as well as success. Granting the general truth in this argument, I deny its validity when applied to experimental science. It is quite correct to eliminate coddling and emotionalism from professional intercourse with students. But a course in experimental science demands that a teacher shall have a psychological and ethical viewpoint quite different from anything that partakes of paternalism. Personal supervision implies a judicious and well balanced combination of all factors essential to good teaching—accurate and available knowledge of the subject from all standpoints, unlimited patience with clumsiness of hand and dullness of brain, continuous poise of body, sympathy tempered with firmness and high intellectual standards, the ability to impart facts unpretentiously but with conviction, a spirit of co-operation at all times but especially when the student is bewildered or in a mental crisis, toleration of the proverbial and traditional habits of students, a perennial sense of humor, unlimited faith in the educative power of experimental science, and an ethical standard as high and broad as Christianity itself. In every laboratory there is constant need of someone great in mind and good in heart to allay fears, encourage those who are being outstripped by their companions, assist in manipulation, answer reasonable questions, give hints at critical times, compel observance of printed directions, aid in the search for sources of error, require repetition if it will correct blunders, and prevent deliberate theft of another's thought.

As the days go by filled with tasks it sometimes seems as if we accomplished little or nothing. We are sure of the loss, for it is persistently evident, but we are not positive about the profit. Let us, however, remember that the bookkeeping of pedagogy is a difficult system and that intellectual growth is not readily transformed into figures. So if we as teachers are careful to keep our souls open for the reception of truth and are sensible, faithful, and honest in the preparation and performance of our share of the laboratory work, then the accounts will show a balance on the profit side.

SOME MODERN NOTIONS IN THE RATIONAL TEACHING OF ELEMENTARY ALGEBRA.

By Jas. F. Millis,
Shortridge High School, Indianapolis, Ind.

It is my intention, in this paper, to suggest a few of those things in a course in elementary algebra which should receive and, in some schools are now receiving, more attention than they have received in the past.

What things should receive emphasis in the teaching of elementary algebra will be determined mainly by the purpose of putting the subject into the school course. Why do we teach algebra to all high school pupils? Why should girls in the high school be made to take algebra for a year and a half? What good are they to get from it? Is the time spent in the study of algebra as it is now studied well spent by the great body of students who do not go to college?

I believe that we will agree that the following three things constitute the main purposes of putting algebra into the high school course:

1. To gain accuracy and speed in the fundamental algebraic processes and a knowledge of algebraic principles;
2. To develop the habit of right thinking;
3. Through the extension of the child's notions of number and number processes to gain a mastery of the world on the quantitative side.

Accuracy and speed in the fundamental processes are fundamental of course. They are essential. But they are the means and not the end. They have long been thought, apparently, to be the end itself. That seems to be a widespread notion even today. Now I claim that the teaching of algebraic processes and algebraic principles for the sake of those processes and principles alone is indefensible. The teacher whose sole ambition is to make the pupil ready to take an examination in algebraic processes is not teaching at all. Rather, he is teaching the subject instead of the child. Then, I repeat, accuracy in using the rules which are arbitrarily laid down for the child in the performance of algebraic processes is not all that is to be gotten from the subject; though this is necessary.

Accuracy is to be gained in several ways. (1) By familiarity with the symbolism of algebra. The pupil must know the exact

meaning of every symbol used. He must know the meaning of general numbers, i. e., letters used to represent numbers. Here is where teachers have always failed in high school work. I shall touch upon this matter later. The pupil must know thoroughly the symbols of operation and the exact order in which they operate. That is, he must learn early how to evaluate an algebraic expression, or function. Too little time is usually spent upon this phase of algebra work. It should be carried throughout the entire algebra course. (2) Accuracy requires a thorough acquaintance with the elementary processes. This is evident. (3) Accuracy requires the formation of careful habits. (4) Accuracy requires long practice—not in solving difficult problems, but by reviews throughout the whole course. These reviews should be systematic, a part of every day's work.

The second purpose in teaching algebra to children, and in my mind the main purpose, is, as outlined above, to develop the habit of right thinking. This, it seems to me, is the main excuse for requiring girls to put a year and a half upon the subject in the high school. To develop within the child the power to reason from given facts to an accurate conclusion—that is the essential thing. It is but an exercise in logic. The teacher who does not have this in mind in the conduct of every recitation in elementary algebra is really not teaching. In getting algebra the pupil should also get a mental training that will make him more able to deal with the problems in other subjects. As Fitch says, in another connection, "we must teach so as to develop the searching and inquiring spirit, the love of truth, and the habit of accurate reasoning." It is evident that for most children the chief good to be obtained from the study of algebra is that power to think correctly that can be used in other studies. We should teach the child how to get from the known to the unknown without assistance.

Now, in all rational teaching of children the following pedagogical principles are involved:

(1) The concrete comes before the abstract; the particular comes before the general; the unknown must follow gradually from the known; processes should precede rules.

(2) The mind really develops only by its own activity.

Hence, in our algebra teaching in the high school we should strengthen the foundations. We should move gradually from the

known to the unknown. We should close the gap between arithmetic and algebra. The notions of number which the child possesses when he leaves arithmetic should be gradually extended. He should grow his own algebra. Teaching algebra by rule is not teaching at all. That is but preparing the student to pass examinations. The child should be led by many particular cases to develop the rules for himself. Rules thrust into the mind from the outside are soon forgotten; but the power which is obtained when the pupil develops his own rules, when he grows his own algebra, is more lasting. Although the reasoning in more advanced mathematics is mostly deductive, the reasoning of young children in beginning algebra must be inductive in nature.

The third purpose of putting algebra into the course of study is, broadly speaking, to gain a mastery of the world on the quantitative side. It is possible for the child to use his algebra in mastering other things. This brings us at once face to face with the question of correlation. How can algebra be made to overlap other studies? How can the child be taught to appreciate and use it in mastering other fields of work in and out of school? What should elementary algebra do in the way of preparing for other studies?

Now, the consideration of the foregoing purposes of teaching algebra in the high school and the consideration of the method of teaching it which the principles of pedagogy have demanded are now causing a revision and vitalizing of the subject. Textbooks are being revised. The tendency is to strengthen some phases of the work which heretofore have been carelessly treated and to place emphasis upon some new things. I shall point out briefly some of these.

In accordance with the principle that in education we must proceed gradually from the known to the unknown, we are trying to bridge the chasm which has long existed between arithmetic and algebra. We cannot bring arithmetic up; so we shove algebra down. We make the approach to algebra more gradual. As algebra was formerly taught, the child was suddenly told on the first page of the book that letters could be used to represent numbers, and he was immediately set to work adding them, subtracting them, etc. The result was that few pupils, when they had finished algebra, could tell the meaning of *a*, *m*, or *x*, or any other letter, when used to represent number. Now

we should take care to teach the pupil the meaning of general, or literal, numbers and not be in such great haste to see them add and subtract. The rational way to do this is to make use of the pupil's present knowledge. Take such a principle as

$$\text{distance} = \text{rate} \times \text{time},$$

which the pupil knows will apply in every particular problem in uniform motion, and show that by replacing the words "distance," "rate," and "time," in the statement of the principle by the first letters of the words, the principle may be expressed in symbols by

$$d = r \times t.$$

Then show that here the letters stand for numbers which have different particular values in different particular problems.

Take the rule for getting the area of a rectangle, which says

$$\text{area} = \text{base} \times \text{altitude},$$

and show that this may be expressed in symbols by

$$A = b \times h,$$

where A, b, and h stand for numbers which have different particular values in different particular rectangles.

Numerous illustrations of this kind will lead to a clear notion of the meaning and advantage of general number. We should reach the general notion from many particular cases. It is wrong to allow the pupil to use symbols until he knows clearly what they stand for.

The notion of the significance of general number, as well as a working knowledge of other symbols such as exponents, coefficients, etc., is most thoroughly established by a certain method of checking work which the pupil should be required to use religiously in the first year's work. This checking process consists of substituting particular values for all general numbers which are involved in the identities that the student is continually establishing. For example, in the problem to multiply $a^2 + ab + b^2$ by $a^2 - ab + b^2$, the pupil gets the product $a^4 + a^2b^2 + b^4$. In the multiplicand, the multiplier and the product let the pupil substitute 2 for a and 1 for b. Then the multiplier becomes 3, the mutiplicand 7 and the product 21, as it should. The work checks. Again he finds the factors of $x^4 + x^2a^2 - 6a^4$ to be $x^2 + 3a^2$ and $x^2 - 2a^2$. By making $x = 2$ and $a = 1$, the given expression becomes 14, and the factors become 7 and 2, respecttively, as they should.

This checking process, which is a new feature of elementary algebra work, serves not only to make clear the meaning of all the symbols of elementary algebra, but it has other good educational values. It teaches the pupil to check his own work, and not to come to the teacher, or to an answer book, for assurance. Thus it makes the pupil independent, self-reliant, and accurate. These are foremost among the qualities which we are trying to develop in the pupil.

In connection with the pedagogical principle that we should proceed gradually from the known to the unknown, to my mind the most rational method of developing the idea of negative number should be the same as that used in developing other new kinds of numbers, such as fractions, surds and imaginaries. Treat negative number as the result of an indicated impossible subtraction, where the subtrahend is greater than the minuend. Thus, to subtract 7 from 3, we have $3 - 7$, or breaking up the 7, $3 - 3 - 4 = 0 - 4$, or -4. Negative number is thus shown to be in nature a subtrahend. This notion of negative number is historically correct. This is how the human race got negative number in the first place, proceeding gradually from the known to the unknown, rather than reaching out into realms outside of algebra and suddenly dragging in the notion of opposites, and trying to make the child digest it.

Negative number, fractions, surds, and imaginary number—all of the new kinds of number have been developed by the same principle, the attempt to make the fundamental processes of numbers universal in their applications.

Another application of the law of pedagogy that the unknown should follow gradually from the known is found in the treatment of the fundamental laws of numbers, i. e., the laws of order, grouping, etc. The tendency to-day is to make these laws more prominent and their use more definite in developing the principles of elementary algebra. To attempt to prove these fundamental laws for the beginner is evidently foolish. Here the method of induction should be used. The pupil should be led by many particular examples to see that these laws hold in arithmetic and that they will hold equally well in algebra. Their application in developing the principles of algebra then becomes a simple matter. After the pupil has become sufficiently mature to put his own thought into the work and has become familiar with algebraic

language and algebraic processes—that is, in an advanced course in algebra—the rigorous proofs of these fundamental laws might well be undertaken. The method of induction is the only method for young children.

In line with the general movement to make the approach to algebra more gradual, to proceed gradually from the known to the unknown, to allow the pupil's mind to develop by its own activity, such difficult principles as are involved in the process of obtaining the H. C. F. by division should be postponed. H. C. F. and L. C. M. by factoring are sufficient for the purposes of elementary algebra. Likewise, cube root by the formula, which is of no special practical use, the general theory of the quadratic, and some other subjects may well be postponed until the pupil is more mature. These difficult topics, which are the bugbear of most students, and which may easily be omitted from an elementary course, can be taken up later in connection with the review of the essentials as a part of the more advanced work.

In the resolution of equations pupils should not be allowed to use the term "transpose" until they have, by many particular problems, thoroughly mastered the meaning of the term. They should be required first to solve many equations by the use of axioms and finally be led to discover for themselves that the use of the axioms may be replaced by the more mechanical process of transposition. Aside from the pedagogical principle involved this method of teaching gives the pupil a clearer notion of the equation and its transformations.

The same facts apply in the case of the term "clear of fractions." In the beginning require the pupil to state each time what it is that he multiplies both members of the equation by, and do not allow him to get the erroneous idea that he multiplies one fraction by one quantity, another fraction by another quantity, etc.

One other point and I shall have finished. A number of things can be done in the way of correlating algebra and other subjects. Three of these things I shall mention briefly.

(1) Pupils have long been taught in algebra that the first letters of the alphabet represent known numbers and the last letters unknown numbers. It is only in algebra that this is done. In the algebraic problems of geometry and physics the unknown numbers are usually anything but x, y, and z. Here is where

algebra fails to properly prepare for geometry and science work. To my mind, the best thing that can be done in algebra to prepare for these other studies is so to teach the algebra that when the pupil takes up the study of geometry and physics the algebra that he finds there will be familiar to him. That is practically the whole battle. Teach the pupil that any letter may represent the unknown number. Use a, M, r, V', and all kinds of letters as the unknown numbers in the equations which the pupil solves in the first year of his work. They are as good as x, and just as easy. We may make use of the actual formulæ of geometry and physics as equations to be solved. Take such a formula as

$$s = \tfrac{1}{2} at^2,$$

which expresses one of Newton's laws of motion. Solve it as a linear equation for a and as a quadratic for t. So for the theorems of geometry. Take the theorem which gives the area of the surface of a sphere:

$$S = 4\pi r^2$$

Solve this as a pure quadratic for r. Plenty of such equations can be had from physics and geometry. And they are as good for the purposes of algebra as any equations in x, y, and z. Evidently we do not have to teach geometry and physics to do this. Just familiarize the pupil with the algebraic language of these subjects.

(2) Most books give a chapter on variables and variation, then make no use of it. As an application of variation it has been found easy to show that equations may be used to express a law of science. Show that Newton's law of falling bodies can be expressed by the equation

$$s = \tfrac{1}{2} at^2,$$

which shows that the distance an object has fallen from rest varies directly as the square of the time. Such work in algebra would be good if it did nothing more than to show the pupil that algebra goes somewhere, that it has practical uses in the world.

(3) The graph is now taught in some high schools. By teaching the graph in elementary algebra a relation between algebra and geometry is established, and a foundation is laid for the use of the graph in science work. My own experience in teaching the graph in the high school has convinced me that it is certainly worth while.

MATHEMATICS IN AND BELOW THE HIGH SCHOOL.

BY L. D. WINES,

Ann Arbor High School.

I fully realize that I have taken a subject that needs a volume for space and months of time for preparation; but it is with no such broad outlook that your attention is asked at this time. During the past few years much has been said and written about just what should and what should not be taught in arithmetic, algebra, and geometry, in our public schools, and much advice has been given as to show how these subjects should be taught, and when and where to place the emphasis on each. And yet, from what one hears and one reads, results are still unsatisfactory. The high school teacher is far from satisfied with the results obtained in the grades, and the college professor and business man are far from expressing satisfaction with the greenness and ignorance furnished by the high schools. That the world is far from expressing entire satisfaction with the college graduate is evident enough from the general flood of facetious editorials spread broadcast as often as the month of June appears on the calendar. This last matter is of little consequence just now. For if the college professor and the man in business once come to the point where they are satisfied with the high school product, there will be little cause to find fault with the college graduate.

When the world, including teachers and pupils, takes the same interest and makes as fine discriminations in intellectual training, oratorical and debating contests, prize essays, public discussions and examinations, scientific and literary societies and their researches and results as it does just now in athletics in general, and I might say in football in particular, then will come the day when little or no fault will be found with the results of either our schools or our colleges. Then also will the day have arrived when no dollar spent for schools and education will be begrudged, and no expense be spared for any legitimate educational project; not even, let us hope, for adequate salaries for the people who are doing the severest and most important work in the world. Perhaps at that time a teacher as well as a washerwoman will be able to ride in an automobile.

---

*Read in the Mathematics Section of the Schoolmasters' Club in Ann Arbor, March 30th, 1906, by L. D. Wines.

A high school graduate is supposed to have spent twelve years in school, during eight of which, in the grades below the high school, he is expected to have mastered about fifty different subjects in arithmetic, extending from notation and numeration through stocks and bonds (things he will probably never see as long as he lives) to a final wind up with a series of a hundred or more problems most of which are of such difficulty as to easily frustrate the efforts of not only a college professor, but also of the most astute business man. Of course these eighth graders cannot do what is expected of them; and so in the high school they are asked to go over the whole ground once more, in hopes that finally they will know how to perform the four fundamental operations readily and accurately enough to use them in simple business transactions.

Our committees of ten and various other members told us a number of years ago to shorten and enrich the course, and our authors tried to do it, and if there are any differences in results, few have been able to observe them. So again we ask the question, what is the reason the grammar school and high school graduate is not up to what we think should be the proper standard? In fact, what is the proper standard? is perhaps the first question we should answer in order that we may place the fault where it properly belongs. What should a high school graduate know, and what should he be, at least mathematically, when in his seventeenth year, he is presented with the coveted passport to life in the world, or the university, or the college? I trust that because little or nothing is here said about what he should be in general, that it is not taken for granted that I am not a believer in anything else than mathematics and mathematical training. I believe in "culture" and "education" in their broadest sense; by culture meaning a lively appreciation of all that is "fine in life," in "art, music, literature, courtesy, friendship, and religion," I believe in Spencer's thorough preparation for "complete living," mentally, morally, and physically. Or as Professor Nathaniel Butler says, in the education which makes "training for social efficiency" the goal of a high school course. That the high school graduate should possess above all other attainments a first class knowledge of his mother tongue and an intimate familiarity with both English and American literatures all will admit.

Now, what should this product of the high school know in mathematics? and if he does not know it, whose fault is it?

In arithmetic he should know that the notation that he uses has a scale of ten, and how to perform accurately and readily the four fundamental operations including integral, fractional and decimal fractional numbers. This ability should include a thorough knowledge of not only the multiplication table, but also of the addition table; an accomplishment which I have found to be very rare. It does seem as though college boys and girls should be able to add numbers without the aid of the fingers, or without stopping to reason out the value of the sum of two integral numbers each less than ten. This is not all that he should know about these elementary affairs, he should know *thoroughly, very, very thoroughly* all the principles of these four rules, for both integers and fractions. He should know that there is what is called a complex fraction and the most expeditious way to simplify it. I was once told by a university professor that his brightest student in calculus quailed every time he met a complex fraction; and I could easily believe him from my own experience in teaching trigonometry.

This graduate should have a good knowledge of factors and divisors and multiples, of tests of divisibility, including some knowledge of casting out the nines, if for no other reason than that he should not be ignorant of everything that is not generally usable. Of course he must be familiar with the various weights and measures in daily use; especially should he have a knowledge of the values of the units of the various systems and how they have been obtained, and are preserved and can be restored if necessary. Then ratio and proportion for use in physics, should be thoroughly taught, as should also the subject of mensuration, which for evident reasons should have a very extended treatment. And let me here observe that whatever of geometry it is best to teach in the grades should be taught with mensuration. A brief treatment of involution and evolution should be introduced, teaching the method of extracting square root and cube root by stupidly following a rule in each case, leaving the reasons for these processes for the high school course. The course in arithmetic can then be closed up with a treatment of the subject of percentage and its applications and, I am inclined to add, a good treatment of alligation, which is so

useful in chemistry and physics. This last subject has been tabooed of late years, we are all aware, but from the necessity which Professor Stevens has found of treating it quite fully in his new work in chemistry perhaps we have been making a mistake.

And now what should he know about algebra and geometry? Briefly, of algebra, what is known "as up to and including quadratics," and of geometry what is known as plane and solid and spherical geometry as treated in any one of a dozen or more good geometries that are now published in this country. Lest this should be taken as a wholesale approval of the average treatise of algebra and geometry, allow a few words in detail. The algebra that this high school graduate should study is one that rests every operation on a solid foundation of principles and reasons; one that takes the utmost pains to prove every proposition and establish every principle just as completely as a proposition in geometry is established. It should contain something more than lists of examples and problems, something more than definitions and rules. It should contain demonstrations that are demonstrations, and they should be so clear and so easy to master that they will stay with one as long as he lives. They should be technical in the least possible sense, containing x as little as possible, and using formulas as little as possible. One case will illustrate. In the proof for the various rules for evolution I am most decidedly in favor of the demonstrations as given in the Olney algebra, and am just as much opposed to the way these rules are demonstrated by the author of most any algebra that has been published in recent years. Of all places where you can make the principles of the decimal system stand out and assert themselves no such other place presents itself in the elementary mathematics. Here you can teach more of the decimal system and hence of other systems than anywhere else. This algebra should contain, and the teacher teach, and the pupil learn, the subjects of equivalence of equations, inequalities and variation. It should also relegate the system of solving quadratic equations by factoring to a back seat, and push forward to its old position the method of solving by completing the square; and after that is thoroughly ground into the bones, then bring forward the methods of solving by formula and the factoring system. The latter I know is a very interesting and at the present

time, a very popular method, and should be thoroughly taught for future theoretical work; but of late years it has been seated on too high a pedestal and should come down. How many cases of quadratic equations which arise in the practical applications of mathematics can be solved by the factoring method, except by a person who is in constant practice? And there is one other subject we must teach thoroughly and as early in the course as possible; that is the subject of logarithms. It should be taught at least as early as the second year in the high school. However desirable an elementary knowledge of the rectangular system of coördinates and its use in the plotting of various loci; however desirable it is to know how to use squared paper, and the slide rule, these and perhaps some other subjects might be somewhat sacrificed to afford time for our students to become familiar with the subject and use of logarithms. The fractional and negative exponent can be introduced by definitions in the arithmetic and logarithms made accessible to students much earlier than is now done.

As to the kind of geometry this high school pupil must master, little needs be said. Several thousand years' use of practically one text has crystallized the subjects so that no book that is likely to be used can lead us far astray. It is now thoroughly understood that plenty of problems for original solution and demonstration must be introduced to sell any book on geometry. There is one point on which we cannot be too careful and that is not to undertake to generalize too early. It is also a question as to how much of the advanced or modern geometry it is best to introduce; but lack of time in the course will not make an appreciable amount possible. It should not be forgotten that geometry as studied in the high school is not for the sole purpose of preparing a boy or girl for the university. It is not to teach him geometrical facts primarily; it is to teach him to use his mind, and keep it on his business; in a word to teach him to think, i. e., to teach him to teach himself, the common end of all true teaching.

Now that we have before us what a high school graduate may fairly be expected to know in mathematics; and, having previously admitted that, in general, he does not know it, the question arises, where does the fault lie? My answer is principally in two parts. It is partly his own fault and partly the fault of

his parents and his teachers, but mostly his teachers' fault.

During my connection with the Ann Arbor High School it has been my lot to come in contact with many pupils from many different schools of many different states, as well as to meet daily the pupils who have come into the high school from our own city; and I can assure you that it is as important for the average boy or girl to come from the hands of good teachers, as it is for them to come of good parents. I have said that the pupil is partly to blame, and it is true; for unless the pupil makes a conscious effort, no matter how intensely the teacher tries to teach, little can be accomplished.

It is certain that heredity and environment working through personality are of great value to every one of us all through life, but as we cannot select the ancestors of our pupils or control to any large extent their environment, we must do as we have always done, take them as they are and do our best.

In what respects then are the pupils responsible for their great mental poverty when about to leave the high school? Among all the reasons I can give, what is called lack of will power is perhaps the most fundamental. This deficiency seems to be at the bottom of all their shortcomings. They do not, in fact they will not, when studying, do as they are advised; they will not stick to a sentence or a paragraph till they strike bottom; they will not learn things thoroughly; they will not aim at something and with their mind on the mark strive to hit it. On every teaching day of my life I am obliged to listen to pupils try to recite in geometry who do not know the hypothesis, who do not know the conclusion, and of course do not know, nor do they seriously strive to find out what must be done to prove the propsition; and yet they want to recite, and they want to get through, and they want to graduate. Whether they want to know something is another question. In the solving of problems in either arithmetic, algebra, or geometry they persistently refuse to give nine minutes to the study of the problem trying to discover the relation of the involved quantities, and then take one minute for the solution. They much prefer to take nine minutes for the solution and none for discovery. They rebel against doing the necessary amount of "dead" work in any of the mathematical subjects which they study. Out of a page of twenty-five or thirty problems if they solve the 1st, 10th and last they think they have

done wonders, and some time later when an accurate knowledge of this subject becomes necessary for further advance, they say they have forgotten. No, they have not forgotten, they never had a chance to forget. Another reason why many of our students do not remember their mathematics is because what little they may have known, they did not know in the right way. Again, many are willing, and do immense quantities of "dead" work, and take pains to learn things in the right way; and when they leave school they know very much of what they have learned. I have seen some of these students of the latter class who could, twenty years or more after leaving school, solve problems in arithmetic and algebra with nearly as much facility as when in school; even though they had not gone to college or followed teaching or any other calling than business.

And yet again, many of my students would get as many ideas out of a paragraph if they read it backwards as they do in reading it as printed. They seem to have cultivated the art of sounding the printed words properly, but not the art of gaining ideas when they read and study. Strive as hard as one may day after day to teach them that this is folly, they seem illy to realize it. This does not appear to be natural, and one can hardly avoid feeling that there is some good reason for it. Whether the methods used in the kindergarten have been practiced all along the course and have left the pupils in a sievelike condition is hard to say. One thing many of us do believe, and that is that kindergarten methods do not develop the will power. However evident it is that "The mind always sees clearly what it really sees, and that we reason amiss only when we speak of what we do not see," however evident this is made to appear, many pupils will try in the next breath to reason without seeing, to commit to memory without understanding, and become most heartily discouraged because they cannot master an idea which they will not allow to enter the mind. The case of the pupil then is simply this: he dislikes immensely to use his brains, and will not do it so long as he can avoid it.

It must not be inferred from the foregoing that all high school students are mentally incorrigible; for it is not so, and the many good and true souls who do their best and who succeed in acquiring a good education are numerous enough to make all our efforts worth while. That more of them are not successful is not alone their fault.

And now how much are the parent and the teacher to blame for the poor results obtained by our schools? That fathers and mothers are responsible as parents and as members of our school boards, to some extent, all will admit. If one could visit the homes of many of our pupils much could be explained and much excused. Still when the conditions seem best, as far as home surroundings go, the pupils are often poorest, and when home surroundings seem poorest the pupils are often the best. That errands must be done, and dishes must be washed, and babies must be tended, are of course conditions not conducive to good scholarship; but if these were the only influences working against scholarship in the home it is quite certain that high school teachers, at least, would not have much cause to complain. The social obligations, the fraternity meetings, the midweek parties and entertainments of all characters at inopportune times, are the things that shatter scholarship, and many times also impair good health. The father and mother in the capacity of parents can and should confine these necessary pleasures to reasonable limits and rational hours and times. In the capacity of members of the school board the parents also have serious and responsible duties to perform not the least of which is to furnish plenty of first class teachers at reasonable pay. Last semester, in talking with one of our students who came from a nearby town, and who had been failing in his algebra, I took occasion to inquire a little into his history. He told me that he had studied algebra one year before coming here. He was first classified in algebra 3, failed there, and put back into algebra 2, failed there and put back in algebra 1. I asked him what he thought the matter was? Well, he did not know. Didn't you have a good teacher in the school you came from? Why, yes, but she had seventy-five pupils in her room, and I guess she did as well as she could. I think she did. The parents in that community need to think a little more of their children and a little less of their money. No teacher should ever have more than twenty-five pupils at a time. A state law obliging boards to pay minimum salaries, and an additional dollar per week per pupil for more than twenty-five children would have a salutary effect on the product of our schools. The state could reasonably exact this condition now that the primary school fund is so large.

Lastly, about what share of responsibility for poor results can reasonably be placed upon the teacher? If I was asked to

name the per cent of responsibility that might justly be attributed to him, I should answer anywhere from seventy-five to ninety per cent, depending on other conditions, some of which have already been mentioned. Emerson says that "what we most need in this world is somebody to make us do what we can do; this is the work of a true friend; of course this also means to show us what we ought to do and then make us do it. As I look back over my school days the studies I did best in, and learned most about, were the ones in which I had good teachers. Of these there were, unfortunately for me, only three, and one of these was my algebra teacher in the eighth grade. One can almost say that everything depends upon the kind of teachers we have. It is true that some scholars will do well with any kind of a teacher, and some will learn in spite of their teachers, but most of us need wise and constant attention. A student in review algebra once made in substance the following statement: "I had a certain part of the algebra with A. and a certain part with B.; somehow I remember what I had with A. but I do not remember anything about the part I had with B." The same boy the same subject, but not the same result.

Here then is the first thing a teacher must be able to do to be efficient and successful. He must be able to secure earnest work on the part of his pupils. If the majority of pupils will not work at home, or before coming to class, they must be made to work in the recitation room to make up for it; therefore the teaching cannot be allowed to take on the character of telling, but of making them *tell* you. The operation by which this is done is sometimes called pumping, and if ever you have tried it you have found it to be hard work. That many of our students learn to question themselves systematically and successfully as the result of the constant efforts of their teachers, there is no doubt; and that wise questions and correct answers have been at the root of all success is equally evident, and could be easily illustrated.

The questioning method of teaching is the one that brings the teacher into close contact with his pupils and determines whether or not the pupil has been in close contact with his lesson; and it might also be observed whether the teacher has been in close contact with his subject. There is not enough pains taken, all through the high school, at least, to see to it that every capable student

does the work that is set for him to do. It takes time and hard work to look over examination papers, as well as other set tasks; but in this way only can a teacher be sure that each pupil has done the necessary work, especially in mathematics. I think I will tell how I once saw a teacher fail to make contact with his pupils. It was in a recitation on a day when the lesson consisted of a certain number of problems (not examples). On entering the room the scholars were all sent to the board and each given a problem to solve. The teacher took a seat and waited for results. One after another some of the solutions were completed, and the teacher, armed with a set of answers, indicated whether the answer was right or wrong. If it was right, the problem was immediately erased by the pupil and another assigned for solution. Not one question was asked, not one thing was done to determine whether the solution was a satisfactory one, or whether it was a solution at all. All that the teacher knew was that at the close of the writing on the board was the same number that was found on a certain page and line of the answer book. The pupil could have found this out with the answer book without the aid of the person who was supposed to be a teacher. At the close of the recitation period, not one half of the students had finished their problems; but a new lesson was assigned for the next day, when it is fair to suppose the same operation was gone through with as before. Not one person in this hearing calls this teaching, not one here present but knows that such work is a fraud, and the teacher who teaches in this way is the worst kind of a grafter; nothing but a drawer of breath and a drawer of salary. And I will guarantee that though there was enough breath drawn, there was drawn too much salary, however small it may have been. This was infinitely poorer teaching than my teacher of algebra used to do in the high school when she would determine if we had solved our examples right by comparing our solutions with hers which she had written out on paper. To simply do in mathematics, to get the answer, is not the only thing desirable, even when you do right and get right answers. To know how it is done and to know why it is done are of more importance. To have the right answer is important, but it is the last thing of importance. For the university boy or girl, as well as for the school boy or girl, there is nothing more important than the why, than the theory. To study

the problem and discover relations, to talk before the class and explain these relations are things of the utmost importance, and any teacher that does not devote more than half the recitation period daily to this kind of work is failing and giving plenty of reason why high school boys and girls are so poorly equipped.

To take each equation in a solution and fully tell how you obtained it, and the next eqûation following, stating the principles used and telling all about it, are the things that are worth doing; these are the things that will stay with one through life, that make mathematics a live subject, and a powerful subject for intellectual development and discipline.

In contrast to this method of teaching is the method sometimes used by mathematical sharks who constantly strive to impress their own great mathematical superiority by using and teaching short cuts. On this point I wish to quote a few sentences from the preface of Finkle's "Mathematical Solution Book:" "It will not be denied by any intelligent educator that the so called 'short cuts' and 'lightning methods' are positively injurious to beginners in mathematics. All the 'whys' are cut out by these methods and the student robbed of the very object for which he is studying mathematics; viz., the development of the reasoning faculty, and the power to express his thoughts in a forcible and logical manner. By pursuing these methods mathematics is made a mere memory drill, and when the memory fails, all is lost; whereas it should be presented in such a way as to develop the memory, the imagination, and the reasoning faculty. It cannot be denied that more time is given to, and more time wasted in the study of mathematics in our public schools than in any other branch of study. The reason for this, to my mind, is apparent. Pupils are allowed to combine the numbers in such a way as to get the answer, and that is all that is required. They are not required to tell why they do this, and why they do that, but, did you get the answer?"

Mathematics taught and learned in the right way cannot easily be forgotten. But even though much of its detail may slip away from us, the mental results are as lasting as the everlasting hills. Disciplinary results are what we must strive for in all teaching. This injunction is now laid upon us with as much if not more force than in the days when the number of classical graduates from our high schools outnumbered all other courses. At pres-

ent, as you all know, the engineering section is the largest; and even though this condition would seem to call for better students in mathematics than formerly, there are many who honestly believe that we do not have as many good students in mathematics now as we used to have when more were studying Latin and Greek, and fewer were playing with "fads and fancies."

This being better teachers, and bringing our students closer to their work and ourselves and making them familiar with all its details is in the air all about us; and we teachers of mathematics in the public schools must not fail to have it include us. Old methods that have failed or have outlived their usefulness must be cast aside, and the new ones adopted. Only recently Dr. Darling, of our medical department, told me that he had discarded old methods of instruction, and that now instead of trying to teach by the wholesale and at arm's length, he takes four students into the operating room with him, and they not only see, but help him and tell him what to do. So we must take our students with us and interest them deeply in their work and our work, if we wish to accomplish worthy results.

There are numerous other reasons why we are not producing satisfactory results; but time forbids that I should more than mention two or three of them.

Many times we make the mistake of assigning problems that are too difficult for our students, and to advance them to a higher grade before they have completed the work of the lower grade. A teacher of music is very careful not to give a pupil a piece of music that is too difficult. If she does, disaster is meted out instantly. We teachers of mathematics should be equally wise, and not give our students work that is too difficult for at least the average pupil in the class. For this reason it is very necessary that the proper kinds of texts should be used in the various parts of the course. Three grades of arithmetic, and two of algebra should be provided. There is no doubt at all but what we are making a very serious mistake when we undertake to teach the beginners in algebra from the same text as that used by those who are completing the subject. My experience on this point is such as to make me feel positive that it is a very grave error for us to continue longer in this course. We should by all means use an elementary text with the beginners.

Another reason why we fail to produce desired results is because of the time when these subjects are taught in our courses.

The arithmetic taught in the grades should be completed by the end of the first half of the eighth year. If some geometry, so called, is taught in this year, it also should be out of the way by this time, and the study of algebra should be begun and continued for the remaining half year and the work in mathematics continued in the high school about as follows:

8		9		10		11		12	
Algebra		Alg.		Arith. and Logs.		Alg.	Alg.	Geom.	Geom and Rev. Alg.

or as follows:

8		9		10		11		12	
	Alg.	Alg.		Arith. and Logs.	Alg.	Alg.	Geom.	Geom.	Trig. and Rev. Alg.

It will be noticed that little or nothing has been said about the teaching of geometry. The truth is that most that has been said is just as applicable to geometry and trigonometry as to arithmetic and algebra. Geometry is to a large extent a disciplinary and a culture study; although its practical applications are just as numerous and just as useful as are those of the other mathematical subjects. Geometry is harder to teach and harder to learn, and its problems more difficult for high school students to solve than are those of the arithmetic and algebra, and yet it is probably true that more students fail in their advanced work in mathematics in college through a poor preparation in algebra and arithmetic than for any other cause.

It will be noticed that I have said nothing about the amount of mathematics required of our graduates either for graduation into business or for entrance into college. I have nothing to say, except that I think the requirements for either or both are just about what they should be, even though there is some agitation in the East to reduce the amount for entrance to college.

In conclusion, "knowledge" has been defined as the "abiding result of some action of the mind." It is therefore necessary if we wish our pupils to acquire knowledge we must see to it that their minds are put in action. They must do their share, and I hope I have made it clear that the teacher must do his share.

A PROPOSED IMPROVEMENT IN PHYSICS TEACHING.

By Lewis B. Avery.

Principal High School, Redlands, California.

I must ask the privilege of making the subject I have been assigned a part of a larger one, or rather to show that the difficulties attending the improvement of physics teaching are but a phase of a general problem in high school work, for which problem I propose a solution, the case of physics being a concrete application.

Later in the paper I will take occasion to recommend the introduction into the high school course of work not at present approved by the university.* In many schools, the present requirement of 15 units fills the four years to the full and such introduction would be impossible. Realizing that the proposed experiment in the teaching of physics is but one of several departures at present demanding trial, and that nothing short of the data of actual experience will satisfactorily settle the debates arising as to the relative values of subjects and methods, I have proposed a mode of relief, the granting of which would depend upon the University.

The change suggested, while adding materially to the dignity and responsibility of the high schools, would tend to promote rather than diminish the co-operation between them and the University.

I am not to suggest improved apparatus or new experiments, although few can surpass me in my interest in such things. I do not expect to show how largely the percentage of error has been decreased in our laboratories or how our boys are earning renown by original research and new discoveries.

Let me refresh the memories of some of you by reference to the high school physics of twenty-five years ago. Physics was then largely a show subject. The professor in the midst of his machines was the envy of the boys and the bewilderment of the girls. Complex pieces of mechanism gyrated and the universe according to Silliman fell into order. In the course of time it became a matter of common report among educational authorities that in all this the minds of many students failed to keep to the track of strictly inductive reasoning and were rather taking

*California.

what they saw on authority. It is noteworthy in this connection that many leaders of today's scientific world were reared on such unscientific pap and pabulum. There followed a movement toward individual experimentation that was overwhelming. Since the boy could not be trusted with expensive apparatus, or even be furnished with it, cheaper forms came into use. The craze for home-made apparatus spread, and was checked only by the requirement of the higher schools that the pupils know more physics even at the expense of sloyd. The improvement in apparatus for student use has been steady and the equipments of high school laboratories, while leaving much to be desired, are generally effective and growing more so.

The text-book in physics has not varied widely from the beaten track. Some have emphasized the utilitarian side of the subject, others have made much of the literary style. Some books have been poor and many have been good, but all in all, the text-book in physics has remained a pretty constant quantity, its field more definitely limited, its material more logically arranged, than that of any other subject in the scientific curriculum. I think, further, that the mode of presentation of the subject today in laboratory and class is probably as uniform the country over as in the case of any other subject taught in the high school.

Now, in spite of the improvement made in the teaching of this subject and in its material equipment, I question seriously whether results show the same degree of improvement and of superiority over other subjects.

I recognize the need of accurate work as a foundation for engineering and of inductive experiment for scientific attainment. But something vital has been lost in the transition from the old physics to the new. I can remember the time when physics was one of the most alluring and entrancing subjects of the course. I cannot find indications that this is true today. The high school pupils do not choose it at all generally when left free in the matter. Indeed, when they go to the university it is rumored that they do not continue the subject unless compelled to do so from the nature of the course chosen, and as in the case of Latin, it seems necessary to classify it among the "infant industries" to be protected. The spontaneous days when physics was a field of wonderland seem largely to have passed.

Teachers of physics in high schools also complain that the more

recent and exacting phases of physics are apparently totally foreign to the nature of a considerable number of students, especially girls, upon whom the course is thrust. This difficulty is obviated in some schools by making physics wholly optional. But to one studying education in any broad way it is evident at once that this is no solution of the problem at all. Physics is the most fundamental in its conceptions and the most practical in its applications of all the sciences. The proposition to leave any portion of those who take a complete high school course with no knowledge of it, is in itself a complete acknowledgement of the educational inadequacy of the present methods.

I take it that the charge to be brought against the present course and method in physics is that they lack the qualities that take hold of the youth, they do not touch them vitally. The work with micrometers, while a valuable and essential preparation for what the university offers in later courses, lacks life. So called inductive methods demand that there shall be no preconceived notions about results and that no thrill of expectancy shall mar their scientific precision. Self control and death may have some points of similarity but their difference is life. The magnificence of the repressed and controlled and directed power of the great scientist is only simulated by the high school student, but in his case, or perhaps better in *her* case, it is generally nonchalance and patronizing disinterestedness.

It remains to locate the difficulty and recommend a cure. The first part of the task has already been outlined.

First: As already intimated, the elementary physics teaching of today, to a great extent, lacks the larger phases present in the old illustrated lecture plan. The inspiration of wonderful outlooks into the field far beyond where the tyro could expect to go in high school but might hope to tread secure at a later day—this is crowded out for lack of time, and perhaps, as being too sanguine for a cold blooded scientist.

Second: The lack of a preliminary acquaintance with the field is another conspicuous source of weakness. That boys in general surpass girls in the subject, tends to confirm the supposition that this is a source of difficulties in physics teaching.

Much gain in time and in effectiveness will be obtained in any field of study if an adequate survey of the entire field precedes the detailed attack upon any part of it. This principle is nat-

urally more effective in closely organized subjects. The lack of such preliminary survey, or preview, is the source of much waste of time and energy through the entire educational course. Did you ever know of a railroad setting its grade stakes without a preliminary survey? Did you ever listen to a person read aloud who gave equal emphasis to all words, including the a's, and's and the's? The result is an early and profound weariness on the part of the auditor. It is the business of the reader to furnish by reasonable emphasis, perspective for the hearer who is so situated as to render a survey of what is coming impossible. The effort of the auditor is then distributed proportionately to the importance of the parts of the sentence and discourse, and economy of effort produces a maximum of interest. The value of the preview of a lesson which teachers are frequently urged to give their pupils, lies in the perspective thereby furnished the pupil. He sees the relativity of its parts and can use his forces economically.

With these ideas pressing themselves home upon me, I have attempted to remedy the defects evident in the physics work given under my direction.

The subject of physics has its five departments of mechanics, including dynamics, heat, sound, light, and electricity, each with its principles to be elucidated, comprehended and applied—departments that are practically separate so far as concerns any coordination that will materially aid the beginning pupil—and I came to the conclusion some time ago that the time allotted to these five fields, after considering the sort of work that is to be done in them, was disproportionately small. Accordingly, I lengthened the course in physics to a year and a half with some improvement in results. But the main objections first enumerated still applied. Inspiration, experience, and perspective were still inadequate. I then arranged the work as we are now successfully giving it and it meets the difficulties that have been mentioned, as well, I believe, as they can be met in the time allowed and under existing conditions.

The aim of the present plan is to give a half year's preliminary survey of the subject, covering the field, and making it familiar in a large way.

For the last half of the third year a course in physics is one of the assigned subjects. No text-book is required or desired. It is non-essential as to where a beginning is made. Complexity is no

barrier. "From the simple to the complex" is the motto of past work in physics. "From the near to the remote" is the motto of the proposed plan. Under this plan, a steam engine can be more profitably studied by the beginner than the simple lever. The need of the study of the simple lever may then be made to appear. We study the simple lever in the light of the steam engine rather than *vice versa*. As a matter of fact, we have begun our course with the study of light. A beam of light from the window or lantern is under control on the lecture table and essential materials are at hand. A list of the questions to be answered is on the board when the class arrive, and the present status of the knowledge of the class is briefly ascertained, together with their shrewd guesses at what results should be. The answers are obtained from the experiments. Questions from the class are encouraged and are rationally answered, if possible. Before the next recitation the pupil writes up carefully notes on what he saw and learned, the same constituting his ticket of admission to the next day's period of experiments and discussion. Little effort is made to test the pupil's knowledge, the aim being to concentrate interest and inspire pupils to interpret what they see in rational terms, and to enlarge the field of view and give bright glimpses of fields beyond. To pull up the sprouting seeds every few days to ascertain progress is discouraging to the growth ot infantile ideas.

The actual results with a single class have been favorable, among the most noticeable improvements are:

First: A portion of our pupils who probably could not do satisfactory work in quantitative physics are now given an outlook into the field and a familiarity with it that every rational citizen in an educated community ought to have. Further work in the subject is wholly optional.

Second: The majority that go on and take the final year of physics, with its text-book and individual laboratory work have enough perspective to be able to economize time and effort.

Third. The increased interest in the subject and in the solution of its problems by those who have continued the subject is clearly manifest.

Fourth: The effectiveness produced in the study of the theory is equally perceptible in the handling of apparatus. A clear knowledge of the end and aim of experimentation and an interest in results tends toward mastery.

The objection which may be made that a preview of the subject interferes with strictly inductive methods might once have had influence with me, but it seems to me without force, after having given both methods a trial. Impartial justice is of slow growth. It is not founded on ignorance. Justice is wrongly represented as blind, although much so-called justice is of the blind sort. Scientific honesty is not best cultivated in darkness.

The remaining and telling objection against the suggested course in California is that the university allows no credit for it, but if the schools are given an opportunity to show the course valuable, the university will doubtless in time allow credit for it. All that is needed is some liberty on the part of the schools to use their own discretion in a small portion of the course. Regarding this limitation of our liberty to attempt this, or any other original work in our courses, I wish now to speak.

Allow me to preface any criticism I have to make as to the practical effect of university domination of our American high school curricula with the statement that I fully appreciate what the universities have done in building up high schools and securing improved scholastic standards. And to any who feel inclined to believe that a total separation from the university is preferable to our present plan of co-operation let me suggest that the independent university, setting its own entrance requirements, virtually establishes the curriculum of tributary secondary schools and the real needs of the high school have then no channel through which the university may be reached, as is the case where co-operation is attempted.

Co-operation between these institutions has been helpful to the high school. I have worked in high schools of two states in which high schools have been largely dominated by the university and in one where no such influence was felt, and I am ready to testify from experience and observation that the advice of the university and its backing form a remarkable stimulus to schools and communities, and that its high and uniform standards serve to overthrow much self-sufficient quackery in teaching. The growth of high schools has been most remarkable where the co-operation has been most pronounced. The admirable high school systems of Michigan, Wisconsin, Minnesota, and California testify to the value of university co-operation. It also behooves us to remember how the backing of the universities has changed

our high school certificates from the wild cat currency of former days into diplomas that have some uniformity of value—even though we may not bank them with these same universities.

Having said this, I wish to insist sharply that there should come a time in the life and development of an institution, as of an individual, when, though still receiving the expert advice of its elders, it should yet be largely freed from the dictation that up to that time may have been highly essential to its welfare.

I believe that the time has arrived when the high schools of California should have growing liberties in this matter of the curriculum and the presentation of subjects in the curriculum, but we are met by filling to the full the four years of our course with work handed down to us—"all the traffic will bear." Again, there are those of us teachers who are next to the problem and the patient, who cannot think we are presumptuous in feeling that our prescriptions ought to be more valuable than prescriptions coming from absentee authority, even though that be expert in its line, and it is to be said that our present curricula as handed down by the "powers that be" are frequently not professional prescriptions at all, but rather, compromises among the apothecaries working for opposition shops.

If past history and present conditions may be taken to indicate the future, high school curricula will change materially in the next one or two decades. Whether such changes will represent merely the shifting ascendencies of university departments or healthy growth from within will depend on whether or not the high schools are given some room for self-directed growth. At present the University of California requires definitely 15 year-units out of a possible 16. It is not to be presumed morever, that any fallible committee will have fitted all the requirements to the capacities of all the schools. Indeed, I am told that most of the high schools find the proper presentation of the 1½ units of algebra of the university requirements in a year and a half inadvisable to attempt, and later some other subject will doubtless be out of joint. Again, local situations arise where owing to the poor preparation of a class, or to poor teaching, it may be advisable to spend more time with one class than with another. Under present conditions, the temptation to pass such a class is very strong. In our own school we are using a half unit extra in the half year of physics required without university credit. Thus a half year-unit or less is the present limit of high school liberty.

All that we need ask from the university to insure continued but conservative changes—such as both university and high school may easily accommodate—is that the diplomas from such schools as may be fully accredited should be accepted for two of the 15 required units. I would not ask a reduction in the number of required recommended units, but simply two year-units which we may assign along lines which we may think best for the good of the cause, the school, the class, and the individual. Let the privilege and responsibility be extended under such safeguards as seem best. I have confidence that it will finally meet general approval, and that it will be a source of healthful growth in the high schools, and will awaken interest among university people in the real problems of secondary education.

I crave your pardon for this digression from the subject assigned to me, but before much can be done in the way of improved methods in any line of the preparatory course, more freedom of action is absolutely essential.

Referring to the main argument under my subject I will sum up by saying that I would have the conventional course in physics optional and preceded by a required half year covering the field. it being the attempt of the teacher to give the pupil, by means of directed observation, well-conducted experiments, and conversation, a coherent and luminous view of the field of physics from all its greater eminences.

It is my belief that such a course is valuable to those of our graduates who do not go on to college that they may become intelligent members of society, able to some extent to discern between science and pseudo-science in the current literature of the day, and to have a sympathy for what is scientific in a scientific age. That it is a course of great interest to them I have proved in practice.

It is my further belief verified by some experience, that those who take the college preparatory year-course in physics, after this preliminary course, will do so with more vital interest in the subject and more efficiency because of the perspective gained.

Finally, should the university repose such confidence in selected and accredited high schools as I have here proposed, I predict such an outcome for the experiment as would vitally improve the educational system of the state and be of more than state interest and importance.

SUGGESTIONS FROM BACTERIOLOGY AND SANITATION FOR THE HIGH SCHOOL COURSE IN HYGIENE.*

By Minna C. Denton,

Lewis Institute, Chicago, Ill.

The following list of exercises is suggested as suitable for demonstration before or by high school classes:

1. Method of inoculation and growth of pure cultures of one or more bacteria in gelatin or agar tubes, the original culture being secured from some bacteriological laboratory or supply house. This exercise may be made to illustrate the rapidity with which bacteria multiply, the nature and variety of products which they form, the methods used for the identification of species, and the nature of the precautions necessary to insure the safety of all concerned, in the handling of disease germs.

2. Determination of relative numbers of bacteria in air from different places. This is accomplished by the exposure of hardened gelatin or agar in a petri dish, for a stated interval of time (say three minutes, or five) to the air of the laboratory, of a crowded classroom at the close of the recitation, of an empty room which has been closed and quiet for some hours, of a room which is being swept in such a way that the air is full of dust, of the outdoor air. The cover is returned to the dish and the dish put away. In the course of a few days each bacterium which fell on the gelatin will have developed into a colony, visible to the naked eye as a spot; and the number of colonies thus indicates the number of original germs.

3. Determination of numbers of bacteria in waters from different sources; e. g., city hydrant water, melted ice, melted snow, bottled mineral or distilled waters. A definite amount of water, say one drop, or five drops, is taken up with a sterile glass pipette, or with a loop of freshly sterilized platinum wire, and mixed with the agar or gelatin in one of the tubes; the contents of the tube are then poured into a petri dish to harden, and left to develop.

4. Determination of numbers of bacteria in milk from different sources; e. g., new milk as fresh as possible from the cow, raw whole milk as delivered by city supply companies, milk that has been allowed to sour, cream, pasteurized milk, sterilized or

*Read before the Biology Section of the Central Association of Science and Mathematics Teachers, November 30, 1906.

boiled milk. The same method may be used as in testing water, except that the great number of germs found in milk makes it necessary to use as minute an amount as possible, or even to resort to dilution with sterile water (i. e., water which has been boiled in a sterile, cotton-stoppered flask for an hour and a half.)

5. The effect of temperature on the growth of bacteria can be shown by placing tubes of sweet milk in ice-water, or refrigerator, outdoors in winter weather, in a holder which stands over the steampipes or register; and observing the differences in the length of time required to sour the milk in the different locations; this indicates the relative rates of growth of the lactic acid bacteria in the milk. Again: three minutes' boiling in a cotton-stoppered test tube will almost always prevent milk from forming a true curd, no matter how long it stands, because this degree of heat kills the lactic acid germs. So that another instructive experiment is, Let three tubes stand side by side in a warm place; *A* containing milk which has been boiled for three minutes (in the same tube in which it stands), *B,* milk which has been pasteurized at a temperature of 155° F., or 68° C.; *C,* fresh raw milk; then note length of time required for each to sour.

6. The effect of light upon the growth of bacteria may be shown by the familiar experiment of covering half a petri dish with black paper and exposing to bright sunlight for some hours. B. prodigiosus makes a good subject for such an experiment.

7. The effect of various disinfectants upon the growth of bacteria may be illustrated, as Professor Conn suggests, by the use, in varying quantities, of corrosive sublimate, carbolic acid, borax, salicylic acid, formalin, salt, and sugar, with raw white of egg in ten times its bulk of water; or with milk; observing the extent to which decomposition, or souring, is prevented in each tube.

Directions and valuable suggestions for other interesting work with bacteria may be found in the appendix of Professor Conn's little book, "Bacteria, Yeasts and Molds in the Home"; in an article by Miss Chapin, which was published in School Science and Mathematics for February, 1905; in Professor W. D. Frost's "Laboratory Guide in Elementary Bacteriology," Part I, chapters 1, 2 and 5.

The apparatus used in making culture media need not be

expensive. The oven of an ordinary cooking stove will serve as a hot-air sterilizer for glassware; a fifteen-cent lard pail with a few inches of water in it and a false bottom or an old piece of cloth to protect the glass from unequal heating, makes a substitute for the Arnold or more expensive steam sterilizers.

If, however, one does not care to undertake the making of culture media, it may be bought, as may also the pure cultures of bacteria, from various bacteriological laboratories, for varying prices; $1.50 per dozen tubes of nutrient agar or gelatin being perhaps a safe allowance to make for this expense. The experiments suggested above would call for about 18 tubes, and 18 petri dishes. (Small sizes of petri dishes may be purchased for somewhat less than 15 cents apiece.) However, one may cut down this list considerably; a dozen tubes and dishes or even half a dozen, may be used to demonstrate the principles involved with less detail.

Valuable as are these experiments for purposes of illustration, since they give reality to the work, yet they cannot do much more than illustrate the instruction of the teacher; since all of these experiments or demonstrations need to be discreetly interpreted and extensively supplemented, e. g., one has to explain carefully to the high school student, that the large number of bacteria in milk does not at all indicate (if it be within certain limits) that milk is less fit for human consumption than is water; since, if the milk has been properly handled, most of these bacteria belong to the lactic-acid forming species, and are quite as harmless as are, e. g., the bacteria which occur in vinegar and are the cause of its production.

As I have just intimated, the chief value of this work in sanitation lies, not in the opportunity it offers for the doing of laboratory experiments with bacteria, for these are best made illustrative rather than an end in themselves; but in the opportunity for training these future citizens to take an active and intelligent interest in the practical problems of personal and public hygiene.

The following topics from sanitation or public hygiene are suggested for consideration:

1. (Introductory.) The nature and occurrence of bacteria, the ways in which they get their food, their methods and rate of reproduction, their reaction to different degrees of temperature, moisture, and light, to the presence or absence of air. An enu-

meration of the ways in which bacteria are beneficial, and the ways in which they are harmful to man.

2. Germ contents of the air we breathe. Relation of bacteria and molds to dust, proper and improper methods of sweeping and dusting a room; rugs, carpets, curtains, draperies and other house furnishings in relation to health; contents of air of crowded rooms—school rooms, theaters and public assemblies, street cars. (For interesting study of the air of over-crowded street cars in Chicago, see City Health Bulletin for November 17, 1906.)

3. The preservation of our food from the action of saprophytic bacteria and molds.

a. By the application of low temperature.

Low temperature imperfectly antiseptic but not germicidal; care of the refrigerator; cold storage products.

b. By application of high temperature and hermetical sealing.

Details of bacteriological technique connected with process of canning fruits and vegetables; use of preservatives in canned goods and (incidentally) of coloring matters; pure food law; ptomaine poisoning.

c. By deprivation of moisture, or drying.

d. By use of chemical preservatives.

Salt, sugar, vinegar, spices, borax, fotmalin, salicylic acid, etc., etc. Dr. Wiley's recent experiments with the effects of small quantities of borax and salicylic acid on the health, and the conclusion which he draws therefrom.

4. Bacteria and the water supply.

What diseases are water borne; sources of drinking water; liability of each to contamination; methods used in testing water and reasons for pronouncing it "safe;" degree in which these considerations apply to the water-supply of the town in which the students live. History of some notable epidemics and what they teach. Means of municipal purification of water—city filtration works, sedimentation tanks, sewage purification, and the like; "field work," or excursions to illustrate these points wherever possible. Means of domestic purification; construction and care of an efficient domestic filter. Other media than drinking water, which have been known to carry typhoid fever—ice, milk, oysters.

5. Bacteria and the milk supply.

Nature and sources of milk flora; diseases which may be due to infected milk; harmfulness of unclean milk. Description of,

oı better, class excursion to, a model dairy, if possible. What the municipality should do toward securing a pure milk supply; history of what has been done in different cities. Milk adulterations and testing. Pasteurization, sterilization, directions for, relative value and practicability of each.

6. Micro-organisms and infectious diseases.

Nature of contagious and infectious diseases; list of such diseases common to human species. Means by which infection enters the body, in each case; means by which it leaves the body; disinfectants and disinfection. Antitoxin; nature and methods of manufacture or cultivation; statistics to demonstrate degree of efficiency. Vaccination; nature and production of vaccine matter; history of Jenner's discovery, or invention, of the process; statistics to prove its efficiency. Relation between Fourth of July celebrations and tetanus cases; how to guard skin abrasions and wounds from this and other infections. Pasteur treatment to prevent hydrophobia and why it is efficient. History of invasion of this country by influenza. Tuberculosis; its exciting and predisposing causes; its different forms in different body tissues; methods and media by which it is disseminated; its prevalence in the country, in the state, in the city in which the student lives; means of curing it; the public warfare against it. Insects as germ carriers; especially flies and typhoid, malaria mosquito, yellow fever mosquito.

The above outlines are intended to be purely suggestive. No teacher would care, perhaps, to cover the field in precisely this manner, with a high school class, even if he had unlimited time and resources. As it is, each teacher of the subject necessarily devotes attention to whatever part of the field he may have best opportunity to work out.

What are some of the sources from which the materials for this course may be gathered? Beyond a few of the most elementary statements and barest facts, they are extremely varied, widely scattered, and require most careful searching. Beginning with the most accessible and easiest to master, I should put Prof. Conn's Bacteria, Yeasts and Molds in the Home, first; Sedgwick's Principles of Sanitary Science and the Public Health, next. Abbott's Hygiene of Transmissible Diseases is useful, though it covers a much smaller part of the field than do the others. A most valuable and attractive aid is Dr. Flick's little book, Consumption a Curable and Pre-

ventable Disease. The reports of state boards of health are invaluable. I have found the weekly bulletin of the city of Chicago Health Department equally so, even before I lived in the city of Chicago; it may be obtained free of charge by writing to the Health Commissioner for it. Even advertising matter is not to be scorned; *e. g.*, one may gain not a little information from the sets of illustrated postals sent out in the interesting of Mulford's Antitoxin, Mulford's Vaccine, etc.

Popular Science Monthly perhaps contains as much material in this line as does any other periodical except the more technical ones. The literary magazines offer occasional articles of great value, such as Miss Fallows A City's Campaign for Pure Milk, in the *Century* for August, 1904; Prof. Calkins' Protozoa and Disease, in the *Century* for April 1904. But it goes without saying, that one must be exceedingly careful to avoid the mass of psuedo-scientific literature offered for popular consumption.

Finally, I would urge what seems to me the great importance of strengthening, or perhaps I should say, building, the high school course in hygiene. These notes that I have presented necessarily indicate only a fraction of what may be done with it, for they touch only that material which follows directly from the application of bacteriology to municipal, household, and individual conduct. Whether it be much or whether it be little, let each one of us do what he can towards the development of what is, unfortunately, almost a new field.

Returns were received from 477 oil and water-gas producing companies, and these show that the total production of water gas in 1905 was 82,959,228,504 cubic feet. Of this quantity 5,547,203,913 cubic feet, or 6.7 per cent, were lost by leakage, etc., leaving 77,412,024,591 cubic feet as the net production obtained and sold. As the quantity of gas made and sold at coal-gas and by-product coke oven works was 40,454,215,132 cubic feet, it appears that the consumption of water gas and gas made from crude oil was nearly twice as much as that made from coal. It also appears that while the average price of coal gas in 1905 was 81.4 cents per 1,000 cubic feet, that of oil and water gas combined was a fraction of a cent in excess of $1 per 1,000 cubic feet. Still further comparison shows that whereas 66 per cent of the production of coal gas was sold as illuminating gas, 77 per cent of the combined production of oil and water gas was used for this purpose.—*U. S. Geological Survey Bulletin 260.*

THE TEACHING OF PHYSIOLOGY.*

By H. W. Norris,

Iowa College, Grinnell, Iowa.

If there is any one subject of the high school curriculum of which the graduate knows the least, and that little largely error, it is physiology. I venture the statement that there is no other subject of the high school course that is so disgracefully neglected by both teacher and pupil as this one; that no other subject has so little preparation made for its teaching, both in the education and training of the teacher and in the preparation for the daily tasks; that in no other subject is there such a mixture of little fact with much fiction; that neither as a study for general culture nor for practical value, is the most of physiological teaching worth much.

In many schools physiology is pushed down out of the high school into the lower grades, in large measure, I suppose, because of its generally discredited state. No one wants to teach physiology, no one will if he can avoid it. I have met but one high school teacher who professed an enthusiastic liking for the teaching of physiology.

Has physiology a place in the high school curriculum? I am not one of those who would gauge the value of a high school study by its relation to college work. I think I may be freed at the start from the suspicion of pleading for better college preparation; for the study of physiology can hardly be said to have any direct relation to any specific college courses. I do notice, however, that college freshmen are wofully ignorant of any knowledge of the fundamental laws and processes of life, that they know practically nothing of their own bodily make-up and functions, that not one in a hundred can give even a correct definition of physiology. Most young men and women leaving the high school are densely ignorant on subjects of vital importance to their own physical well-being. Some of these subjects obviously can not be treated in ordinary teaching, most of them can. The most valuable assets that young persons can possess are healthy minds in healthy bodies and the knowledge of how to keep them so. Most of this should be learned at home; little of it is, for parents in general are in these particulars

*A paper read before the Central Iowa Association of Science and Mathematics Teachers, Ames, Iowa, Dec. 1, 1906.

deficient in both precept and practice. The public school must remedy the lack of home training in the matter of clean, healthy living. The crying need in high school work is not better preparation for college, but better preparation for life.

Is not physiology a practical subject? What can be more valuable than a knowledge of the laws of our own being? The loss of time due to periods of illness, and the consequent diminished wage-earning power, the expense of doctor's bills, etc., the lowering of life energies due to physical derangement, the actual shortening of life, these are frightful, and to a great extent preventable wastes. Young people have too often the notion that they are a law unto themselves, and that by leaving it to the Lord and the doctors all will come out right in the end. What folly to educate in knowledge of everything but our own physical selves! I maintain that physiology has an important place in a high school course. I doubt if physiology pure and simple has a place in grades below the high school. From the kindergarten up there should be, as I suppose there usually is, some attention paid to the simple laws of health, hygienic living, and sanitary surroundings. But in the high school period, when the boy and the girl are being mysteriously transformed into the man and the woman, then, more than at any other time is there need of systematic training in the fundamental laws of organic life.

In spite of all the good things on which we boastfully pride ourselves, the fact is that as a people we are surprisingly ignorant of fundamental physiological processes, of the ordinary laws of health, of the simplest facts of food values, the cooking of food, the care of the body. If we are to preserve our superiority as a race it must depend to a very great extent upon physical strength. The waste of life at the present time is appalling, yet how little of that waste is necessary. How few people have any knowledge, practical or theoretical, of food values! How few know anything about the relative digestibility of different foods! Take the matter of sugar. As a nation we consume enormous quantities of sugar. It is a most valuable food, and a most dangerous one. Few people realize that a large percentage of human ills of the present time are due to the unintelligent use of sugar. It has taken us a long time to realize the dangers in adulterated foods, but we have yet to learn how to use pure foods properly. The reckless, un-

intelligent use of drugs is also responsible for a large share of human suffering. Medicine in the world at large does more harm than good because of the general ignorance of the physiological effects of drugs upon the living organism.

Whatever may be the condition of the pupil's knowledge on physiological topics in general, there is one field in which he is sure to excel in ignorance, that is the physiology of the nervous system. The nervous system! That bugbear of physiological teaching! How many teachers have found it convenient to end a term's work with the chapter just preceding that on the brain. Yet the fact is that nervous processes and activities are fundamental operations, to which all other processes are subservient. It is possible to study anatomy and yet give no attention to brain structure, but not for one moment in physiology can we ignore the nervous processes. The youth is prodigal with his expenditure of nervous energy, and little does he estimate its value. Yet rarely do we see a young person break down from overstudy. Nervous breakdowns can more often be traced to the candy habit and other practices that interfere with nutrition, than to overworking the nervous system. There are no brain foods. The best thing for the nervous system is a healthy stomach supplied with nutritious food. In the teaching of physiology we slur over its most valuable parts, the treatment of the nervous system. Pupils from the public schools who come into my classes know practically nothing about the anatomy of the nervous system, to say nothing of its physiology.

Says a recent writer in answer to the question, "How shall the destructive tendencies of modern life be met by the individual?" "First of all a physical education is needed to develop, strengthen, and preserve the body. In spite of mechanical and scientific advance, we are far behind in respect to the rules of simple and healthful living." Some of these fundamental facts should appear in the teaching of physiology. It is not enough to teach that alcohol and tobacco are dangerous things, it should also be emphasized that any food, however valuable, is dangerous if used improperly. "Food," says Mrs. Richards, "is the only source of human power to work or think." Enormous as are the evils of alcoholic intemperance, the evils of food intemperance are greater in quantity, if not in quality. Untold wastes in life would be saved if young people had any

adequate ideas of the relative values of foods, medicines, etc. Says Professor J. P. Norton: "The salvation of civilization and the race lies in the hands of exceptional men." A knowledge of the simple laws of health and nutrition would go far towards increasing the number of exceptional men. Physiology, then, has a practical value that can not well be overestimated.

As long as parents are as ignorant as their children of the ordinary laws of health the public school seems the only place where the young can receive instruction in such matters.

But physiology is not only of practical worth, it has a culture value. A knowledge of the marvelous adaptations of form to function, a realization of the intricacies of the chemical and physical processes that go on in living matter, of the subservience of all organic processes to law, these and other facts of life, if known, can not fail to make sympathies broader, judgments clearer, and individual action nobler. I grant to no subject a greater cultural value than physiology, if it is taught rightly. Aye, there is the rub.

Physiology ought to be taught as a live subject, for it is supposed to deal with the functions and the activities of living beings. But as long as it is given a subordinate place in the curriculum, as long as anybody is supposed to be capable of teaching it, just so long it will not be taught respectably. We do not expect a teacher to gain a working knowledge of latin in a summer vacation, nor of algebra in a single session of a teachers' institute, but there are teachers galore of physiology who keep just one chapter ahead of the class. For many years I have been called upon to recommend teachers for high school positions in science, but not once to my recollection has physiology been specified as a subject of any importance.

I maintain that the most important provision for thoro teaching in physiology is a teacher thoroly trained. All the apparatus, skeletons, and specimens that could be furnished, and whose importance I would not underestimate, would be of little value without the skilled leadership of the person trained not merely in text, but also in knowledge of facts gained at first hand. We would not think of securing a teacher in botany whose knowledge of plants is limited to text-boks, but we have no hesitation in handing over a class in physiology to a teacher who has no first-hand knowledge of the subject.

I believe that our colleges and training schools are to a great extent responsible for this discreditable state of instruction in physiology. Physiology as taught in most of our colleges is little better than that of the high schools, either in grade or method. Physiology should be taught as tho it were a subject of the utmost importance, as it really is. The teacher can not present it as a living vitally important subject unless he has learned it as such. Ask the ordinary student of physiology for sofe description of the content of the subject; he will be likely to sum it up under these heads: bones, muscles, stomach, heart, lungs, and nerves, yes, and alcohol and tobacco. But how the various organs are grouped together into one working whole, how one depends upon the other, in short, the correlations in the living body, are about as real to him as a fourth dimension in space. In most institutions physiology is little more than anatomy. To be sure anatomy must be at the foundation of all physiological studies, but it should be nothing more. The teacher not only should have a knowledge of structures, gained by the study of actual things, but he should have studied experimentally the processes of digestion, circulation, nervous and muscular activity, etc. I do not advocate the introduction of laboratory practice in physiology into the high school, nor do I disapprove of it, but I do plead for a live teacher who can, if necessary, resurrect a dead subject.

Another potent factor in the present stagnation in the teaching of physiology in the high school, is, I doubt not, the compulsory temperance teaching so prevalent in this country. When, as a prerequisite to publication, and to the subsequent use in the schools, a text must be submitted to the inspection of a committee whose judgment is based not upon fidelity to fact and correct pedagogical presentation, but upon the number of pages devoted to alcohol and tobacco, the larger the number of pages and the more virulently intemperate the language employed the more favorable the verdict; when, I say, the author must submit to the mutilation of his text and the distortion of his methods by those who care little for the truth and much for a propaganda, then we can not hope for a presentation of physiological truths that will command the respect of either teacher or pupil. However poorly equipped the teacher may be he is not willing to teach as truth that which both he and the pupil know to be false. Until the blighting influence of this "tem-

perance" supervision of physiological teaching is removed, we may expect to see high schools avoiding the subject as much as possible.

But we must be doing something to guide our young people into clean, healthy lives. Ignorance even in our age is the chief enemy of good health as it is of good morals. And good health and good morals are more closely related than we sometimes think. Some instruction must be given in our high schools that help the pupils to a knowledge of their own physical selves. I care not under what name such teaching goes, whether botany, biology, zoology, or domestic science. If by masquerading under some other name physiology can be presented from the standpoint of unbiased truth, without the deadening restrictions of so-called temperance inspection, then so let it be.

The physical and moral health of the next generation is largely determined by the public schools of today. We can not escape the responsibility. Nor shall we have met that responsibility until we have made physiological instruction an all-important component of the curriculum.

SPIDER STUDY IN A ZOOLOGY COURSE.

By Wilbur H. Wright,

McKinley High School, Chicago.

The study of spiders in any fairly detailed manner is not usually taken up in high school courses. This group, however, offers some advantages not always found in the types usually taken.

Except in winter spiders are abundant almost everywhere out of doors, under dead leaves, on plants, on fences or in old buildings, cellars or the corners of rooms. In this region the large black and yellow Argiope found in webs on grass and bushes, especially around marshes, and the very common Agalena, weaving a flat web with a funnel-like entrance in grass, on the bases of trees and in many other places, furnish suitable material for observation in the autumn. Or the common house Epeiras and their round webs may be still more accessible. Spiders of some kind may be found in almost any season, but the smaller species are more difficult to study. Even in December, around Chicago, such types as the pale Clubionas and dark

jumping spiders, Phidippus, may easily be collected in considerable numbers. They are found in their sheet-like winter webs in old newspapers lying on the ground and pieces of the paper bearing web and spider may be brought to class. This may serve to show not only the means of protection of these types in winter but their position in the winter web.

Spiders may best be collected by covering with an empty bottle and then dropping them into alcohol or formalin. The colors may fade somewhat. The use of too strong alcohol at first, tends to distort the specimen.

It will be seen then that spiders are more easily collected than many kinds of insects. Teachers who have an opportunity to do field work will find here a very inviting prospect. Autumn is an especially good time for this and the common Epeiras, orb weavers, may be looked for in barns, houses and on fences. The coloration, size and markings of the spider, its position in the web, if the spider is in the web, and the form and size of the web may be studied. The rays, inner spiral and outer spiral may be tested as to adhesiveness. Difference in size and the character of the palps will serve to separate the males from the females. The males do not usually weave webs of their own.

The study of the large black and yellow spider mentioned above, Argiope riparia, will be one of especial interest on account of the size of the female and her brilliant coloring. The web also is large and interesting in character. Note the wavy band up and down across the center, the spot in the middle where the spider stands and her position. Argiope transversa, having transverse lines on the abdomen, may be found and a comparative study made.

As a contrast to the orb weavers mentioned above we may study the common Agalena naevia, before alluded to. The large size of the spider, its coloration, the character of the web and its lack of adhesiveness are all points that will excite interest. This field work will also suggest the character of the food of spiders. The jumping spiders, lying in wait on fence posts or on plants and the crab spiders with their flattened bodies and peculiar gait are among the most interesting of all although they do not catch their prey in webs.

The cobwebs of spider areonauts streaming from posts everywhere at times in our Indian summer also excite much interest.

The reason for this peculiar habit, which is found among the Erigones and the young of many larger species, is unknown. But the very fact that he is told that it is unknown leads a pupil to speculate as to possible reasons.

The study of cocoons, their position and variation in different types will naturally come here. Some will be found in crevices in wood work, some hanging in webs, some on dead leaves, logs and in various other places. Sometimes they are attached to the body of the mother. It is usually easy to get at least two different types of cocoons, one from crevices and one from the webs.

For the many teachers who are unable to do field work this group offers opportunities in laboratory ecology. Some of the species found in cellars and houses will spin their webs if placed in a glass jar. The character of the web may be studied and the spider in various positions. I have also been able to keep one of the web weavers under observation on a cactus under a bell jar. The spider may be taken out and allowed to drop toward the floor and the web supporting it examined. Then the spider may be made to climb up its own web. Most pupils have never looked closely at things of this kind. They may see the spinnerets in operation.

Cocoons containing eggs or young may be found hanging in the web of a common house species and studied *in situ* or brought to the laboratory and examined. I have rarely seen a class more excited over a new discovery in zoology than by the finding of small live spiders in the broken cocoon. The diminutive spiderlings fell out in a small shower, each suspended by its web and spinning it as deftly, in this first contact with the light of day, as an old spider. These cocoons, when examined, illustrated to the class several things, among them the fact that spiders do not go through the metamorphoses of some of the insects they had studied and also the stage of development of that species at that season. The suggestion that the young of some species are said to live by eating the weaker individuals in the cocoon may be made here. Some of the adult females also treat the males very rudely, at times killing and devouring them. The peculiarities of unsocial relations here furnish a wide field for discussion.

For the study of external structure the large Argiope riparia

is especially well suited. They may be placed in small vials of alcohol or formalin and used year after year. The principal divisions of the body, the form, size, coloration of the cephalothorax and abdomen, and the number, position and comparative length of the legs may be studied without the lens. With the hand-lens the palps, mandibles, epigynum and spinnerets may be examined and the eyes located as to number, character and position. The position of the eyes should be compared in representatives of different groups as Agalena and Epeira or Argiope. The legs, feet, palps and mandibles will need to be examined with the compound microscope also. The male of this species should be compared here with regard to size and the structure of the palps, and in more detail if possible.

Agalena naevia may be used in place of these but is somewhat smaller and the coloration less striking. The spinnerets are, however, more easily studied. Or large specimens of the common house Epeiras or some of the large wolf spiders, Lycosidae. sometimes to be obtained from dealers in biological supplies, may be used.

After all one of the most striking characteristics of this group is the spinning of the web. Its use in producing the cocoon for protection of eggs and young will be seen when the cocoon is collected and studied. Its use as a protective winter covering for partly grown or adult forms has been alluded to in the case of Clubiona and Phidippus. Its usefulness as a means of escape from enemies may be shown by allowing a live house spider to lower itself from some extended object. But it should be emphasized here that because certain kinds spin nests or cocoons it does not necessarily follow that they spin webs for catching prey. We may here suggest the classification of the types into two groups, the hunting and the cobweb spiders. Of the hunting spiders, which spin no webs for catching prey, a few o fthe jumping or running or crab spiders may easily be collected.

This will lead to a study of the snares of the cobweb spiders and at least three types are worthy of discussion in elementary work. The flat web of Agalena, with its tubular entrance, may be brought in in fairly good condition. The loose, netlike webs of Theridium may usually be found in rooms or cellars of schools. Of the orb weavers work *Eperia* and *Agiopa* furnish good ex-

amples. The construction of the last type may be explained with the aid of a diagram or the lantern.

The internal structure of the spider can best be illustrated by a diagram and sofe of the pecularities of the digestive system and respiration correlated with those of insects and crustaceans. Whether the class begins in mid-year or in the fall, this study could follow that of insects and a good deal could be done in a short time. This would open the eyes of the pupils to a new world, especially in evidence in our Indian summer.

It would be difficult to find a field where more can be readily observed than here. The peculiar character and movements of the crab spiders slipping sidewise into a narrow crack, the rapid movements and brilliant metallic colors of some of the common jumping spiders and the more dully colored Lycosa, perhaps dragging her egg sac after her, may easily be observed in the autumn by looking on fences and under logs.

These studies will naturally lead to a discussion of different types, trap-door spiders, tarantulas, the bird spider and many others. For collateral reading the encyclopedias and nature study books furnish some material. Mr. Emerton's "Common Spiders" will be especially needed and the popular stories by McCook are to be found in most public libraries. Miss Patterson's "The Spinner Family" and Comstock's "Insect Life" and "Manual for the Study of Insects" should be at hand.

THE NEW BIOLOGICAL GARDEN AT OAK PARK.

By Thomas Large.

Oak Park, Illinois, High School.

The rapid occupation by residences of convenient natural fields for Zoology and Botany work in Oak Park, Illinois, has caused the establishment by the Township High School of a Biological park, on a small scale, in the grounds about the new building now in course of erection. These grounds occupy about ¾ of a city block and of this an unoccupied plot 144x190 feet has been recognized as an outdoor laboratory by the High School Board of Education, at the earnest request of the Principal and Teacher of Biology. A small sum of money has been appropriated for excavating a pond and for water supply. The latter is from the roof of the building. The subsoil is a comparatively impervious clay

hence no difficulty is anticipated in securing a good basin with very natural conditions for plant and animal life.

The school-garden idea as hitherto carried out in America usually provided for raising of cultivated plants for the purpose of training pupils in care of gardens for pleasure or profit. The Oak Park garden seems to be a step in a different direction. Here it is proposed to simulate various natural conditions as nearly as possible and to induce to live as nearly as may be all of the plants and animals found native to the Chicago area. Parts of the ground will be given to marsh and shore plants, aquatics, prairie and forest, and a space is set aside for a sand-dune awaiting the supply of sand. In a space on the North side of the building between the East wing and the Assembly Hall, ravine plants, mosses, ferns and other shade loving plants will find congenial surroundings.

The planting will proceed gradually, chiefly by volunteer work of students, instructors and other interested persons. Each planting will be recorded and definitely located by a system of plotting in squares of 100 sq. ft. each, located by letters and numbers, lettering in series from West to East and numbering in series from North to South. The stock of animals will be chiefly those seeking the environment thus afforded though fishes, crustacea and batrachians will be introduced. Students will be encouraged to bring animals from a cyclops or "doodle-bug," to snakes or mammals, stopping short only of Crotalus or Mephitis. All such additions will receive careful record. The mosquito problem will be left for the "top-minnows" to solve.

It is hoped to make this an outdoor laboratory in every sense. By "malice of forethought" the basement floor was made to appear to "the powers" the proper location for laboratories and subsequently said powers were persuaded to open a doorway from the hallway on this floor directly into the "fernery" so that classes in fair weather, can pass as readily to the marsh or pond as they can to the laboratory or recitation room.

This arrangement is not intended as a substitute for excursions to natural fields, as the Chicago region is too interesting to be neglected, but rather that it shall encourage and give purpose to the extended trips while furnishing collateral illustration and working material.

How it will work in actual practice remains to be seen. Suggestions will be welcomed as it is not too late to modify plans to some extent should it seem well to do so.

ADVANTAGES OF MIGRATION RECORDS IN CONNECTION WITH BIRD STUDY IN SCHOOLS.*

By Frank Smith,

University of Illinois, Urbana.

This topic does not necessarily involve any discussion of the advisability of a certain amount of bird study for our secondary school pupils. The importance and desirability of such work is taken for granted. It is rather a question of means which may be used to make the work more effective.

I am not ready to advocate the idea that the entire time of our students in bird work should be given to a study of migration activities and a record of the same; but I offer for discussion three or four considerations which seem to me to be in favor of making such a study a quite important part of the bird work.

In illustration of the effects of keeping such records, I have in mind the case of a young man who came to the University of Illinois this year from a high school in which he had acquired a great interest in bird life. I happen to know that this young man has been going out nearly every morning this autumn for a one to two hour bird trip before breakfast. It seems that this has been his practice much of the time since he studied birds in the high school, and it contributes to his health as well as to his enjoyment in life. His immediate purpose in these trips is the continuation of his records of arrivals and departures of migrating birds. He has kept such records for four or five years and the more extended the time which they cover, the more he is prompted to sacrifice in his efforts to complete them. It is improbable that any other motive would impel him to make trips in early morning hours in all kinds of weather. One needs to listen to him but a few moments when he is telling of such trips to see that the young man feels fully repaid for his efforts. There occur to me a number of other instances in which the interest in bird work has been increased and made more permanent because of the desire for additional records for comparison with others already made.

It is reasonable to expect that for the sake of completeness, the student who keeps such records will be more anxious to learn the identity of all bird visitors than will those who study birds from other points of view, and again, that for the sake of com-

*From a paper read before the Biological Section of the Association of Science and Mathematics Teachers, Nov. 30, 1906.

pleteness, he will make more frequent trips than he would be likely to make, if he were interested chiefly in other phases of bird work. With the exception of a month or two in winter and again in midsummer there is abundant motive for the student of bird migration to get into the field and to get there daily if possible.

It is but a short step from a study of the facts of the arrival and departure of birds to a desire to know of their whereabouts at other times of the year, and so there naturally arises a motive for the study of the seasonal and geographical distribution of our summer residents and migrants and for learning of the bird's activities throughout the whole year. Such knowledge leads naturally to a desire to learn something of the causes of these annual flights which take some of our summer friends to the other side of the equator in winter and back in spring, and which result in such wonderful flights as those of the American Golden Plover which in June nest within the Arctic Circle and by the next October have gone with their fellows to the Argentine Republic for a six months' outing, and then continue their annual travels by a return to the Arctic regions for the next nesting period—an annual journey of more than sixteen hundred miles.

The study of the causes which have led up to the present migratory activities is, of course, quite beyond the reach of pupils of our high schools. Explanations are not to be found by any amount of making or studying of records of first arrivals and departures. There is, however, a fine opportunity for the pupil to correlate the movements of the birds as shown by his records, with the meteorological conditions shown by the weather maps and to test the relative importance of such factors as change in temperature, in the direction of the wind, in barometric pressure and in the food conditions, in stimulating the birds to make the single flights of which their annual journey is composed. If daily records are kept, it will not take long during the spring migration for the pupil to discover that there are much more extensive movements on some nights than on others, both in the number of species and of individuals. In fact quite a large part of the number of first arrivals will be found to have been noted on a comparatively small number of days. The most extensive movements in spring, in the central states, will nearly always be found to occur at times when an area of low pressure is approaching from the west and the Mississippi Valley is being swept by south-

erly winds. Such conditions in the latter part of April and early in May are sure to be accompanied by great bird waves. As birds of all sorts of food habits from Green Herons to Warblers may come in the same night, it will be clear that it is not chiefly food conditions that stimulate the flight. If the student compares his autumn migration observations with those of spring, he finds that in the autumn the greatest activities are manifest when there is a rising barometer and north wind and so the lowering barometric pressure in spring is not to be credited with having the chief influence. As between the direction of the wind and the change in temperature the pupil will perhaps have a harder time in deciding which is more influential in stimulating the flights, but the attempt will be worth while. For such studies it is highly desirable to keep a file of all the weather maps of the season.

If practicable for the pupil to compare his data with that from other latitudes, some facts can be ascertained as to the distances that birds may fly in a single night.

Since records of this sort may become the basis for comparison with other data and for subsequent generalizations, they should be as complete and accurate as it is possible to have them and this gives occasion for impressing the pupil with the necessity for absolute integrity in dealing with data of a scientific nature. Because of this feature of the work care should be used in stimulating rivalry between observers lest the desire to out do others be a temptation to make too hasty identification or even to dishonesty which in scientific matters is unpardonable.

To summarize, I would advocate the keeping of migration records for the following reasons: (a) The pupil who keeps such records is likely to acquire a stronger and more sustained interest in bird work; (b) The records are likely to furnish a strong motive for the identification and study of all the kinds of birds that visit the locality; (c) The prominence which such records gives to the migration activities creates a desire for a wider knowledge of seasonal and geographical distribution; (d) It gives the pupil contact with some unsolved problems which he can attempt to solve in part and get some useful training in the effort. The fact that he is on the borderland of the unknown is likely to stimulate his interest and efforts; (e) It affords opportunity for enforcing the importance of accuracy and integrity in scientific matters and so may aid in developing character.

There are doubtless insuperable difficulties in the way of securing daily work of this kind from all pupils, but it can be had from some of them. The allowance of extra credits and provision for cooperative work has sometimes been successful. Although actual first arrivals of a large number of species is desirable, yet we must not overlook the fact that such data, if accurate, are valuable even for a small number of common birds and especially so if they can be compared with similar data from a considerable number of well distributed localities.

MODEL-MAKING BY ZOOLOGY STUDENTS.*

By Frederick Colby Lucas,
Englewood High School, Chicago.

Every teacher has his hobby. I suppose that I have been asked to give this paper because model-making has been a sort of hobby with me for the past few years. I fully realize that one teacher cannot do the same things and in just the same way as some other teacher; that what may be helpful to one under one set of circumstances may not appeal at all to another. My apology for presenting this particular phase of Zoology teaching is, that it is a method which has proved very successful and helpful to me in my work and with my class of pupils. If what is said in this paper about models may not meet your approval, if you are inclined to call it kindergarten work or to doubt whether the time expended is not out of proportion to the results obtained, let me ask you to suspend judgment until you have actually tried, with your own classes, this making of models.

Let me first explain what I mean by the term "model." Please note that I do not mean glass models nor those made of papier maché (such as the Kny Scheerer models for example). These have their uses and are well known to you. In the course of this paper I shall call your attention to three things. First, representations of entire animals in modeling clay. Second, representations of sections, chiefly cross sections, cut out of paper. Third, simple anatomical charts on the same plan and suggested by the well known Jaeger charts used in teaching physiology. It is my intention to explain briefly how I make

*Read before the Biology Section of the Central Association of Science and Mathematics Teachers, Nov. 20, 1906.

use of each of these types. Before doing so, however, let me emphasize the point that these models are to be made by the student himself, after the study of the actual specimen, with only a minimum of help and direction from the instructor. I did not begin this way. Originally, I made the model to help clear up some difficult point or to correct some inaccurate conception, as I suppose you have done many a time. Then it occurred to me that it would be much better for the pupil to work out the thing for himself. And from this point there has been a gradual evolution. At first I made the work voluntary but now I require a certain amount of model-making from each pupil. Of course it consumes time to do this in the regular laboratory period, but I hope I shall be able to convince you that it is time well spent. However, if the time cannot be spared the making of models may be assigned as outside or home work.

First, as to the use of clay. This substance is known also as composition clay and as plastolene and is to be obtained from all dealers in art goods. Since it is clay mixed with oil it keeps indefinitely and may be used over and over again.

I have found it helpful to have pupils make clay models in cases such as the following: After the study of the single cell (for example the starfish egg), which has included a carefully labeled sketch, the pupil is asked to make a model out of clay representing his idea of the shape of a typical, undifferentiated cell. A majority, according to my experience, will make the model in the form of a disc, because they have not as yet learned the significance of focusing. A discussion follows in which is developed the fact that the cell has thickness, and the pupil is required to correct his model. Since a pupil is more apt to remember what he does than what he reads or hears about, the correct notion of the cell will thus be firmly impressed upon his mind,

Another case. After an introductory study of the Hydra the student is given some composition clay and told to make a model of the animal. I find this exceedingly helpful in bringing out the relation between the tentacles and the hypostome, a relation which must be clearly understood if a correct drawing is to be made. And we must not forget that when a pupil recites correctly about any fact, that it does not necessarily follow that he has apperceived it. It is important to keep in mind in considering the value of models that a student may make a

sketch of a specimen and label it correctly without clearly understanding it, but that he cannot make a correct model without having a pretty accurate understanding of the specimen. In the former case he has the specimen before him and his drawing is in a sense a copy, while his laboratory directions tell him how to label. The model shows at a glance whether the student has understood the specimen under consideration. This relation between drawing and model-making is especially true of sections seen under the microscope and suggests the special value of the paper models of which I shall next speak. Before leaving the subject of clay models, however, let me just call your attention to the fact that the soft kneaded eraser used in drawing makes a fair substitute for clay and has the advantage of not soiling the hands.

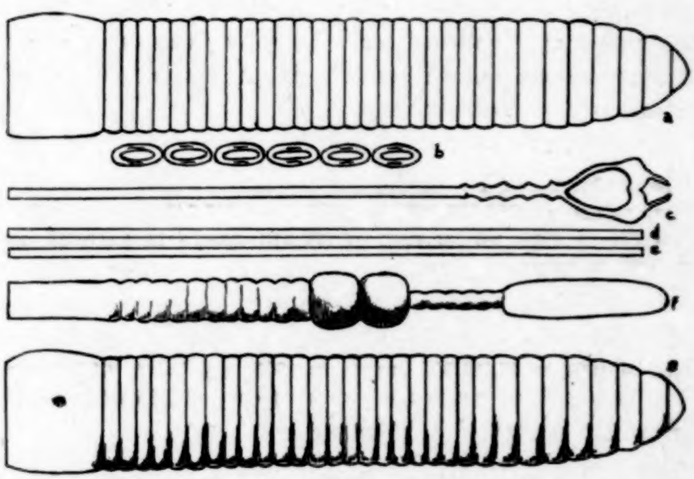
With regard to clay models I make no claim of originality. My own pet scheme is the cutting from paper, diagrammatic representations or models of cross-sections of animals and the making of anatomical charts. I have found both exceedingly useful and I will in a few words explain how I have used them.

After a study of the cross-section of the Hydra there is required a paper model of the same. By means of different colors, the cell layers are to be represented. The coloring is the same as is used by me in all diagrams and models to represent the same layers and their derivatives. For coloring, either water colors or the wax crayons are used. I find the latter better if the student has not had some previous experience in the use of water colors. I have sometimes required a model of a longitudinal section of the Hydra. In that case I give the additional information that the section should pass through the center of the animal, that the tentacles are hollow, and that the Hydra may be supposed to have six (or five) tentacles. The pupil of course has never seen a longitudinal section so this piece of work is a very good exercise in use of the imagination or may we say in objectification. It also serves to emphasize the difference between a longitudinal section and an animal split longitudinally.

Again, after the drawing of the cross-section of the earthworm is completed I require another paper model. This is even more helpful than the model of the Hydra. Many pupils have to try three or four times before they make a correct representation. If you doubt the wisdom of making models let

me ask you to try this experiment. Let one class simply make a sketch of a cross-section of the earthworm and let another make a model in addition. Then quiz the two classes and see which remembers and understands the better. I, myself, find that after the pupil has had to cut out the various parts and put them together in the correct relation, this relation is very firmly fixed in his mind. He knows that the blood vessels as well as the alimentary canal are hollow. He understands the double tube plan for he has had to cut out the two rings which represent the cross-sections of the tubes. Perhaps he loses some part after it is cut out or perhaps at first he cut out circles instead of rings for the sections of hollow structures. These mistakes, if they are corrected, by the pupil himself, serve only to make him remember more readily the actual condition. Let me again emphasize the fact that the value of these exercises is attained only when the pupil himself makes the model with only hints and suggestions from the teacher.

Finally a word about the anatomical charts. If you will glance at the sample exercise, here shown you will see the



earthworm diagram as furnished to the pupils. This model is taken up *after a study of the dissection of the earthworm.* Each part of the diagram is cut out and the several parts pasted together in the proper relation. The completed model will give you an idea of the final result. You will notice that in this, as in all cases, the models are to be labeled and pasted upon a sheet of paper and are then to be placed in the notebook. I

have found this anatomical chart of the earthworm very helpful to the student, aiding him greatly in his comprehension of the anatomy of the animal.

I have also worked out a somewhat similar model in the case of the clam. This exercise I have sometimes substituted for a drawing so as to give variety to the work. The model is always followed by two other exercises. That is, the pupil is asked to make diagrammatic cross-sections through the two regions indicated by vertical lines in the completed model.

In conclusion I would like to say that I have also used paper models in connection with the flower study in botany with very satisfactory results. That is, for our first flower study, we built up a flower instead of tearing one to pieces. Somewhat to the amusement of the students we name this sample flower *Humbugio paperensis.* You will note that model-making is the antithesis of dissection and therefore has the value of having a completed product as the result instead of a much dilapidated specimen.

This very briefly is my method with regard to models. I hope I have made some of you feel that the work is worth while. I feel sure that if you will try it with your classes, if you have not already done so, the results will justify you in making it a feature of your regular work.

The production of gold in the United States increased from 3,910,729 ounces, valued at $80,835,648, in 1904, to 4,265,742 ounces, valued at $88,180,711 in 1905, an increase of 355,013 ounces in quantity and of $7,345,063 in value.

The production of silver increased in quantity from 55,999,864 ounces in 1904 to 56,101,594 ounces in 1905, a gain of 101,730 ounces; but it increased in commercial value from $32,035,378 in 1904 to $34,221,972 in 1905, a gain of $2,186,594.

PROBLEM DEPARTMENT.

IRA M. DELONG,

University of Colorado, Boulder, Colo.

Readers of the Magazine are invited to send solutions of the problems in this department and also to propose problems in which they are interested. Solutions and problems will be duly credited to the author. Address all communications to Ira M. DeLong, Boulder, Colo.

ALGEBRA.

36. *Proposed by P. G. Agnew, Washington, D. C.*

Coal is on the deck and coal is running on the deck from a chute at a uniform rate. Six men can clear the deck in an hour, eleven men clear it in twenty minutes. How long will it take four men to clear the deck?

Arithmetical solution by Mrs. Minnie McGrath Darling, Roanoke, Ill.

Suppose 1 man removes 10 units of coal per minute (any other number in the supposition would do).

(*a.*) Then 6 men remove 60 units per minute, and 3,600 units per hour.

(*b.*) 11 men remove 2,200 units of coal in 20 minutes.

In either *a* or *b* the deck is entirely cleared. But 1,400 more units of coal had to be removed in 60 minutes than in 20 minutes, and as the amount of coal on the deck at first is the same in *a* as in *b*, the 1,400 units must have run on in 40 minutes, or at the rate of 35 units per minute. At this rate, 2,100 units run on the deck in an hour. But by *a*, 3,600 units of coal can be removed in an hour. Therefore, 3,600 units minus 2,100 units, or 1,500 units, must have been on the deck when the work began. Since 35 units run on per minute, it will require $3\frac{1}{2}$ times the work of one man to clear away the coal as fast as it runs on. But 4 men, the newly employed force, can remove 40 units per minute. That is, they make a gain of 5 units per minute over the amount of coal running on the deck. $1{,}500 \div 5 = 300$. Hence the 4 men must work 300 minutes, or 5 hours, to clear the deck.

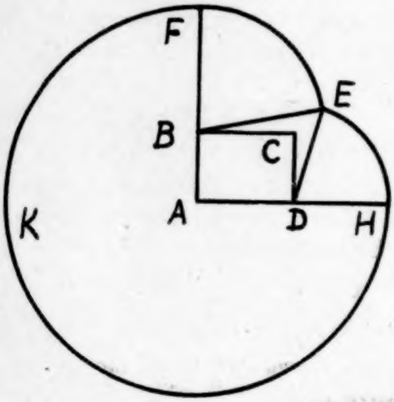
44. *Proposed by W. H. Hays, Columbia, Mo.*

A cow is tied to one corner of a house, which is $20' \times 30'$, with a 60 ft. rope. Find the area over which she can graze.

Solution by E. L. Brown, M.A., Denver, Colo.

Let $AD = 30$, $AB = 20$, $AF = AH = 60$

Then will $BF = BE = 40$, $DE = DH = 30$, and $BD = 36.06$



Having sides of triangle EBD, we find

BED = 60°, EBD = 46° 6′ 7″, BDE = 73° 53′ 53″, and its area equal to 519.62

Area triangle BCD = 300 ∴ area BEDCB = 219.62

ABD = 56° 18′ 37″, and therefore FBE = 77° 35′ 16″

BDA = 33° 41′ 23″, and therefore EDH = 72° 24′ 44″

Area sector AHKF = 8482.32

Area sector EBF = 1083.33

Area sector EDH = 568.73

∴ total area = 10354 sq. ft.

GEOMETRY.

45. *Proposed by John W. Scoville, Syracuse, N. Y.*

Four spheres, each of radius r, are arranged in a pyramidal pile, each sphere touching the other three. What is the inside surface of a box shaped like a regular tetrahedron, that will just enclose these spheres?

Solution by I. L. Winckler, Cleveland, O.

The altitude of the regular tetrahedron whose vertices are the centers of the spheres is

$$\frac{2r\sqrt{6}}{3}$$

Hence the radius of the sphere inscribed in this tetrahedron is ¼ of its altitude or

$$\frac{1}{4} \times \frac{2r\sqrt{6}}{3} = \frac{r\sqrt{6}}{6}$$

The radius of the sphere inscribed in the tetrahedron whose faces touch the spheres, is equal to the radius of the sphere inscribed in the tetrahedron whose vertices are the centers of the spheres plus r, or the radius of this sphere is

$$\frac{r\sqrt{6}}{6} + r = \frac{r(\sqrt{6}+6)}{6}$$

The vol. of a regular tetrahedron = area of its surface × 1-3 radius of inscribed sphere.

Hence vol. of required tetrahedron =

$$\frac{E^2(\sqrt{6}+6)\, r\sqrt{3}}{18}$$

where E = the edge

Also the volume of a regular tetrahedron = cube of edge times

$$\frac{\sqrt{2}}{12} \text{ or } \frac{E^3\sqrt{2}}{12}$$

Hence

$$\frac{E^2(\sqrt{6}+6)\, r\sqrt{3}}{18} = \frac{E^3\sqrt{2}}{12}$$

From this $E = 2r(1+\sqrt{6})$

And thus we find the surface of the required tetrahedron to be $(28\sqrt{3}+24\sqrt{2})r^2$

46. *Proposed by T. M. Blakslee, Ph.D., Ames, Ia.*

Prove by elementary geometry that the midpoints of the three diagonals of a complete quadrilateral are collinear.

Solution by proposer.

Let ABCD be the quadrilateral, AC and BD meeting at E, AD and CB at F. Also let DBCG and FBEW be parallelograms on BD and BC, BF and BE as adjacent sides. Let CG and DG cut AD and AC in S and I. M, N, L are the midpoints of AB, CD and EF. N and L are also the diagonal points of the two parallelograms.

First; to prove SI parallel to FE. Let

$$\frac{AC}{AE}=\frac{m}{n},\ \frac{AD}{HF}=\frac{h}{k},\ \text{then}\ \frac{AI}{AE}=\frac{hm}{kn}=\frac{AS}{AF}$$

Second; triangle GBW gives LN parallel to WG.

Third; since EC divides WG externally in ratio $\frac{WE}{GI}$ and FD divides WG externally in ratio $\frac{WF}{GS}$, and triangles FWE, SGI are similar, it follows that FD, WG and EC meet at A.

Fourth; triangle ABW gives LN parallel to WA and containing L the midpoint of BW. LN therefore contains M, the midpoint of AB. Thus L, M, N are collinear.

APPLIED MATHEMATICS.

47. *Proposed by Wm. B. Borgers, Grand Rapids, Mich.*

A bicyclist coasting down a 6 per cent grade due west finds the acceleration of gravity just counteracted by the wind, producing uniform motion. He then turns 30 degrees north, where the grade becomes 10 per cent. The direction and velocity of the wind being still the same, still produces uniform motion. Find the direction of the wind.

[Remark.—By a 6 per cent grade one means that the tangent of the angle is .06. However, for small angles, the sine and tangent are practically the same and therefore the sine is sometimes employed. --Editor.]

Solution by E. L. Brown, M.A., Denver, Colo.

Let α = angle of 10 per cent grade

Let β = angle of 6 per cent grade.

Let x = angle between first course and direction of wind, measured north of west.

Let g and f = acceleration of gravity and wind respectively.

By conditions of problem

$$f\cos x = g\sin\alpha\cos\alpha.$$

$$f\cos(x-30) = g\sin\beta\cos\beta.$$

$$\therefore \frac{\cos(x-30)}{\cos x}=\frac{\sin\beta\cos\beta}{\sin\alpha\cos\alpha}=\frac{19802}{11958}$$

$\therefore x=57^\circ\ 40'\ 3''$ or N. $32^\circ\ 19'\ 57''$ W.

CREDIT FOR SOLUTIONS RECEIVED.

36. Minnie McGrath Darling, C. R. Merrifield, E. L. Brown.
37. C. R. Merrifield.
40. This problem will be kept open another month.
41. H. E. Trefethen.
42. H. E. Trefethen.
43. H. E. Trefethen.
44. E. L. Brown, I. L. Winckler (two solutions), H. C. Whitaker.
45. Russel P. Harker, I. L. Winkler, P. G. Agnew, H. C. Whitaker, E. L. Brown.
46. T. M. Blakslee (three solutions), E. L. Brown, I. L. Winckler.
47. E. L. Brown, H. C. Whitaker (N. 32° W.). Three incorrect solutions were received.

Total number of solutions, 26.

PROBLEMS FOR SOLUTION.

ALGEBRA.

53. *Proposed by G. E. Ripley, M.S., Valley City, N. D.*

Prove that

$$\sqrt[3]{6+\sqrt{\tfrac{980}{27}}}+\sqrt[3]{6-\sqrt{\tfrac{980}{27}}}=2.$$

GEOMETRY.

54. *Proposed by I. L. Winckler, Cleveland, O.*

Describe a circumference which bisects three given circumferences. (From Chauvenet's Geometry.)

55. *Proposed by E. L. Brown, M.A., Denver, Colo.*

Divide a given triangle into two equivalent parts by a line perpendicular to one of the sides.

APPLIED MATHEMATICS.

56. *Proposed by W. E. Tower, Englewood High School, Chicago, Ill.*

A sphere is hung from a hook in a vertical wall by a string equal in length to the radius. Find the inclination of the string, its tension, and the pressure on the wall if the sphere weighs 10 lbs.

MISCELLANEOUS.

57. *Proposed by H. C. Whitaker, Ph.D., Philadelphia, Pa.*

A square contains just 2 acres of ground. A cow fastened to a stake in the middle of one side is allowed to graze one acre inside the square. How long is the rope in feet?

MATHEMATICAL NOTE.

Several answers have been received in reply to Mr. Plunkett's communication in Vol. VII, 1907, No. 1, page 59. The first reply is here given:

In reference to the note in SCHOOL SCIENCE AND MATHEMATICS concerning the correctness of the proposition that "In the same circle, or in equal circles, arcs whose extremities can be made to coincide are equal," the author of the text has probably pointed out previously that any chord of a circle subtends two arcs and that unless otherwise stated the *lesser* is intended when the word *arc* is used, in which case the proposition is true.

There is, however, a more subtile objection to this proposition. The idea of the inequality of the two arcs of any circle subtended by any chord (not a diameter) *presupposes* a knowledge of the conditions under which two arcs of a circle are *equal*, so that such a proposition is truly an "argument in a circle," but unfortunately of the kind which good logic teaches us to avoid.

G. W. GREENWOOD,
Roanoke College, Salem, Va.

RESUME OF CURRENT MAGAZINES FOR TEACHERS OF SECONDARY MATHEMATICS.

Teachers of high school mathematics will find interest and profit in the following recently published mathematical papers: In the Bulletin of the American Mathematical Society for January, 1907, page 166, is a paper on "A New Approximate Construction for π," by Mr. George Pierce; and on page 197 is a good review of McCormack's translation of Dr. Ernst Mach's "Space and Geometry in the Light of Physiological, Psychological, and Physical Inquiry."

In the November, 1906, *L'Enseignment Mathematique* (Paris and Geneva), "Logarithms before Napier," by A. Aubry; "Pure Mathematics and Approximation," by L. Kollros; "Graphical Method of Determining the Real Roots of the Equation $x^3 + px + q = o$," by E. Brand; "Demonstration of a Proposition in Linear Equations," by G. Dumas. For those who read French these papers will be of considerable interest.

In the *School World* (London, Macmillan) for September, 1906, is a paper on "The Curriculum of Secondary Schools," by Hon. and Rev. E. Lyttleton, M.A.; another on "The Secondary School Curriculum and the Training of Teachers," by Arthur C. Benson, M.A., and a third on "The Balance of Studies in Secondary Schools," by T. E. Page, M.A. These three papers refer to the situation in English schools, but they are illuminating to the American teacher as well.

In the *American Mathematical Monthly* for December, 1906, is a "Note on the Addition Theorem in Trigonometry," by Dr. G. A. Miller.

DEPARTMENT OF SCIENCE QUESTIONS.

FRANKLIN T. JONES.

University School, Cleveland, Ohio.

Readers of this Journal are invited to send answers to the questions and solutions to the problems, also to propose questions and problems which will be of general interest. Address all communications to the editor of the department.

This department is designed to serve as a medium of exchange of ideas on questions and questioning in the sciences. Questions will be printed from various sources—college entrance examinations, text-books, school examinations, ets., etc. Comment is invited. Suggestions and criticisms as to character, adaptability and usefulness are desired.

As examples of questions which might be asked in review, the following are printed:

1. The formula for ethane is $C_2 H_6$. Calculate the specific gravity of its vapor (a) compared with hydrogen, (b) compared with air.

Find the proportions by weight and by volume in which ethane gas will combine with oxygen. (College Entrance Examination Board.)

2. Write the equations representing the volume relations, (a) when carbon monoxide burns in oxygen; (b) when ammonia gas is decomposed into its elements. Give the relative numbers of molucles taking part in each reaction. (Sheffield Scientific School.)

3. What is the percentage of copper in crystallized copper sulphate? (Harvard.)

4. How much chlorine by weight and by volume (at S. P. and S. T.) can be obtained from 100 grams of rock salt? (Princeton.)

5. How many feet does the minute hand of a clock travel in twenty-four hours if it is four feet long? How much does it move for each complete swing of the pendulum if it ticks forty to the minute? (Lodge's Elementary Mechanics.)

6. A train starts from rest. At the end of five minutes its velocity is thirty miles per hour. What is its acceleration? In what units is it expressed? (Princeton.)

7. A mass of 150 grams is thrown to a height of 1200 cm. With what velocity will it return and what energy will it possess? (Sheffield Scientific School.)

Buried in newspaper articles, lectures, books, and magazines is the material for unusually suggestive problems. The following was found in Muir's translation of the Third Edition of Lassar-Cohn's "Chemistry in Daily Life," page 135. (Lippincott, 1905.)

8. A cannon, exhibited by Krupp at the Chicago Exposition, when charged with 115 kilos (253 lbs.) of prismatic gun-powder, propelled a shot weighing 215 kilos (473 lbs.) to a distance of 20,226 meters (12.5 miles;) the flight of the shot occupied 70 seconds, and the highest point attained was 6,540 meters (4 miles) above the earth, while the height of Chimborazo is only 6,421 meters (3.99 miles.)

What questions based on this problem could fairly be asked a class in Physics? Answers will be given in a later number of this Journal.

As any find such material as the above, it is to be hoped that they will send it in for publication.

ATMOSPHERIC DUST.

The importance of dust in the economy of the atmosphere is not to be underrated, but neither should it be overestimated. If dust is present in the air, the light reflected therefrom has various tints of gray or red, depending on the size and nature of the particles of dust, but if no dust is present, light may be reflected from any minute particles of water or ice that happen to be present, and these are not generally called dust. Molecules of water or ice sometimes form minute drops by gathering about particles of dust as nuclei, but they can also form such drops without dust as nuclei, and must frequently do so. However, if neither dust nor water were present in the atmosphere, we should still have our ordinary blue sky light, and some sunset sky colors. The deep blue of the sky is due almost entirely to the selective dispersion of the various waves or rays of light that come from the sun, by the action of the molecules of the constituent gases of the atmosphere. The ability of these molecules to absorb and reflect any given wave length depends upon the relative dimensions of the wave and the molecule. The exact relation has been carefully worked out by Lord Rayleigh, whose formulae explain not only the blue color of the sky, but also the polarized condition of that light. Dust particles and ordinary water or ice particles are relatively so large that they reflect all rays of light, with a slight possible predominance of the red rays or long waves; consequently the hazy whites and grays of foggy weather and the dirty reds of the Indian summer may be attributed to dust and vapor, which in fact obscure the deep blue sky light.

Aqueous vapor in its finest condition, when it begins to condense without the help of dust nuclei, has the power of selectively reflecting the longer or bright blue as distinguished from the shorter dark blue of the pure upper sky; the resulting bluish haze may often be seen under favorable atmospheric conditions when we look at a distant landscape, and especially in the pure air of oceanic islands. The blue haze off the west coast of Scotland is proverbial. This haze was first studied in the laboratory by Tyndall, when he produced it unexpectedly by allowing dustless moist air to expand inside the vacuum tube.

The beautiful colored sunsets observed in connection with the eruption of Krakota, and especially the brilliant colors brought out by Prof. Carl Barus, of Brown University, in his study of cloudy condensation, are not due to dust nor to the selective reflection by fine particles, but are examples of a very different process, i. e., the colors of thin plates, or what Newton called the colors of thin films. The central portion of each little sphere of water transmits a minute beam of sunlight which has been reflected to and fro within the sphere, and its waves have interfered with each other. Some have been reinforced and others have been annulled. The former give the beam that is seen by the observer, and its color depends on the diameter of the sphere or the thickness of the film of water.

In general therefore, our beautiful atmospheric colors are not altogether due to dust.—*Monthly Weather Review.*

THE METAL CALSIUM.

Researches upon the metal cæsium have been carried out by E. Rengade of Paris. Seeing that the metal cæsium has the property of igniting spontaneously when brought in contact with air, it seemed of interest to find out whether this action is not due to the presence of moisture, and to observe how the metal acts when in contact with pure and dry oxygen. The apparatus which is used here consists of a horizontal glass tube. At one end it connects with an oxygen supply or a mercury pump. The cæsium is contained in an aluminium tray. After making a vacuum, we introduce oxygen in small quantity, and the metal now melts and oxidizes at once, absorbing all the gas. As it was supposed that the apparatus might contain a slight trace of moisture, another form was used. A small glass bulb having a fine point containing the metal distilled *in vacuo* is inclosed in an oxygen tube. In the bottom are some pieces of metaphosphoric acid. After several weeks the small tube is given a shock, so as to break off the point. In this case we have a sudden oxidation of the metal and it glows brightly. At low temperature the action is less. At —40 deg. C. the metal soon blackened, but it does not glow, while at —80 deg. C. the effect is much slower. The apparatus just described also serves to observe the oxidation products in cæsium. If we allow oxygen to arrive slowly over the aluminium vessel, a liquid is first produced having gold reflections, resembling the ammonium metals. With a new supply of oxygen it is soon changed to a black mass. Then the oxidation stops, and the metal must be heated to go further. The mass swells up at first, and then contracts. No doubt a series of oxides are thus formed. If we heat the product in oxygen up to a definite fusion and let it cool we obtain a yellow crystalline mass. Analysis gives the formula Cs_2O_4 for this oxide. The aluminium tray is not attacked when quite dry, but other metals such as platinum, gold, silver, also glass, are strongly attacked under the same conditions. This oxide of cæsium which is thus prepared is of a golden yellow color and is darker when hot. Its density is 3.77 at 19 deg. C. Its fusing point in an oxygen chamber is 515 deg. C. This body is decomposed at once by water, giving off oxygen and forming hydroxyl according to the reaction $Cs_2O_4 + 2\ H_2O = 2\ CsOH + O_2 + H_2O_2$. Carbonic acid has no action on it when cold, but when slightly heated it gives the reaction $CO_2 + Cs_2O_4 = CO_3Cs_2 + O_3$. Dry hydrogen reduces the peroxide of cæsium near 300 deg. C., giving off oxygen and water vapor. The reaction is complex in this case. The first effect of the hydrogen is to form water vapor, and the latter then acts partially upon the remaining peroxide, decomposing it and giving off oxygen. It also attacks the aluminium trough, which is much corroded, with formation of aluminate of cæsium at the same time as the hydrate of the metal.—*Scientific American Supplement.*

WHAT IS MEANT BY THE WORD "ARTESIAN."

The significance of the term "artesian" is discussed with great care by Mr. Myron L. Fuller of the United States Geological Survey in Water-Supply and Irrigation Paper No. 160. While there is considerable diversity of practice there is nevertheless a general tendency to give the term one or the other of two meanings, and about fifty geologists throughout the country have expressed their willingness to accept any definition agreed on by the majority of active workers on underground-water problems.

Discussing the original use of the term artesian (as applied to flowing wells first observed in the town of Artois, France), the use of the word in recent scientific literature, in Europe, and the present scientific and popular use of the term in this country, Mr. Fuller makes clear that no definite meaning can be assigned to the word artesian in a publication unless definition is given in the same paper. It is even found that the same writer employs it differently in different publications.

The predominant scientific usage of the term is for all wells in which the water rises; in other words, for those exhibiting the hydrostatic or artesian principle. In popular practice it is applied, in addition to the uses previously mentioned, to deep wells in general, especially those in rock, and to a certain extent to any drilled wells yielding water of good sanitary quality.

After discussing the arguments for these various uses, Mr. Fuller gives the following definitions which were agreed on by the members of the Division of Hydrology of the Survey as the most expedient at the present time.

Artesian principle.—The artesian principle, which may be considered as identical with what is often known as the hydrostatic principle, is defined as the principle in virtue of which water confined in the materials of the earth's crust tends to rise to the level of the water surface at the highest point from which pressure is transmitted. Gas as an agent in causing the water to rise is expressly excluded from the definition.

Artesian pressure.—Artesian pressure is defined as the pressure exhibited by water confined in the earth's crust at a level lower than its static head.

Artesian water.—Artesian water is defined as that portion of the underground water which is under artesian pressure and will rise if encountered by a well or other passage affording an outlet.

Artesian system.—An artesian system is any combination of geologic structures, such as basins, planes, joints, faults, etc., in which waters are confined under artesian pressure.

Artesian basin.—An artesian basin is defined as a basin of porous bedded rock in which, as a result of the synclinal structure the water is confined under artesian pressure.

Artesian slope.—An artesian slope is defined as a monoclinal slope of bedded rocks in which water is confined beneath relatively impervious covers owing to the obstruction to its downward passage by the pinch-

ing out of the porous beds, by their change from a pervious to an impervious character, by internal friction, or by dikes or other obstructions.

Artesian area.—An artesian area is an area underlain by water under artesian pressure.

Artesian well.—An artesian well is any well in which the water rises under artesian pressure when encountered.

OCCURRENCE OF WATER IN CRYSTALLINE ROCKS.

While the laws governing the occurrence of ground water in unconsolidated materials and in porous sedimentary formations are now generally understood, little has been written concerning the sources of supply for wells in the so-called crystalline rocks. For this reason, when an opportunity was presented in connection with an investigation made by members of the United States Geological Survey of the underground waters of Connecticut, special attention was given to the occurrence of water in such rocks. Mr. E. E. Ellis of the Survey has contributed a paper to the annual hydrologic report (Underground-Water Papers, 1906) in which the general results of this investigation are set forth.

The water of the crystalline rocks occurs, so far as it can be secured by wells, wholly in joints, faults, or other fracture openings, the pores and schistosity planes being too close to permit active circulation. The water seems to occur largely in the vertical joints or faults, especially in the sheeted zones consisting of numerous crowded fracture planes. In Connecticut a common spacing betwen the surface joints is 3 to 7 feet, but in some cases they are much farther apart. At depths of more than 50 feet the space becomes greater owing to the dying out of subordinate joints.

The spacing of tne horizontal joints is rather regular. In the first 20 feet below the surface they average 1 foot apart, for the next 30 feet from 4 to 7 feet, and in the following 50 feet they are from 6 to 30 feet or more apart.

The most favorable points for water are at the intersection of two or more of the joint systems, the circulation being often concentrated at these points.

It is impossible to foretell the succes or yield of a well in crystalline rocks, but the chances of a moderate supply are at least as good as 9 in 10. The character of the water obtained is in general excellent, both for domestic and manufacturing purposes, and is usually soft. Hills and places where the soil is thick are the most desirable locations for drilled wells. In general it is better to abandon a well and seek a new location if not sucessful when a depth of 250 feet has been reached, as the possibilities of a supply below this depth are much less than at shallower depths.

The average cost of 123 wells, averaging 108 feet in depth and yielding a mean of 12.7 gallons a minute, is $4.25 a foot.

TWO SPECIAL ALASKAN MAPS.

Ever since the discovery of gold placers on the Seward Peninsula in 1898 that general area has been as attractive to the public as was the Klondike in the spring of the previous year. Miners, operators, and investors have flocked into that part of Alaska and numerous towns have sprung up. The chief of these, in fact the metropolis of the north, is Nome. From a rough mining camp it has been rapidly transformed to a corporate city with its own government and most of the modern improvements and facilities that are found in cities of equal size in "the States."

A peculiar feature of the placers which have made Nome famous is the occurrence of beach deposits. These extend along the shore of Bering Sea in front of the present location of Nome for a distince of twenty miles. The value of the gold taken from these beach placers is estimated at no less than $1,000.000, but this is small compared with the value of gold taken from the nearby creek and bench claims, which have already produced $30,000 000 and are still adding to the world's wealth of yellow metal.

The importance of this region was early manifest. In 1899 the United States Geological Survey made a geologic and topographic reconnaissance of the southern part of the Seward Peninsula.

The data and maps published as a result of this expedition furnished valuable information to miners and investors, especially in regard to roads, ditches, available sources of water supply, and other features that are important in the economic development of mines. These maps lack, however, the details that are essential in maps used for such engineering purposes as making preliminary estimates, laying out grades and locations for future construction, etc., and it was to furnish additional data that a more detailed map of this region was made. It is published in two sheets called the "Nome" and "Grand Central" specials.

The Nome Special includes the area lying between 64° 25′ and 64° 40′ latitude, and 165° and 165° 30′ longitude. The Grand Central. Special includes the area between 64° 40′ and 65° latitude and 165° and 165° 30′ longitude. These sheets are published on a scale of 1:62500, approximately 1 inch to the mile, with a contour interval of 25 feet, referred to mean sea level as a datum.

KANSAS ASSOCIATION OF MATHEMATICS TEACHERS.

The Kansas Association of Mathematics Teachers held one of the most successful meetings of its existence in Topeka December 26-27, 1906, under the direction of Prof. H. B. Newson of the University of Kansas acting president.

In accordance with a plan that the interest should center about the mathematics of the grades the following program was carried out:

"Algebra as Now Taught in the High School,"

J. S. Carson, Wichita High School.

"Mathematics of the Grades Exhaustive Rather than Extensive,"

T. P. Downs, Beloit.

"Algebra in the Last Year of High School,"
W. H. Ganett, Baldwin.

"The Extent of Arithmetic and Algebra in the Grades,"
R. E. Hartsock, Pittsburg.

"Mathematic versus Arithmetic," Prof. H. B. Newson, Lawrence.

"Algebra from the Viewpoint of the College,"
Prof. C. H. Ashton, Lawrence.

The discussion resulted in the adoption of the following:

(1) *Resolved*, That it is the sense of this association that one half year of algebra should be included in the last year of the high school.

(2) *Resolved*, That there should be a change for the better in the present state text in algebra.

The following committee was appointed to report at the next meeting on subjects to be eliminated from the text on Arithmetic in present use: Prof. C. H. Ashton, Univ. of Kas.; Supt. L. A. Lowther, Emporia; Chas. A. Wagner, Hutchinson; A. M. Bogle, Kansas City, Kas.; Miss Emma Hyde, Iola, and Miss Effie Graham, Topeka.

Many new subscriptions were received for SCHOOL SCIENCE AND MATHEMATICS, the official organ of the association.

The officers for the coming year are:

CHAS. A. WAGNER, Hutchinson, Pres.
A. M. BOGLE, Kansas City, Kas., Vice-Pres.
EFFIE GRAHAM, Topeka, Sec'y-Treas.

SCIENCE AND MATHEMATICS SECTION OF THE HIGH SCHOOL DEPARTMENT OF THE PENNSYLVANIA STATE TEACHER'S ASSOCIATION.

On Dec. 26, 1906, a meeting was held in the high school building at Williamsport, Pa., for the purpose of organizing a society for the improvement of teaching mathematics and science in the secondary schools of Pennsylvania. A call for such a meeting had been issued and sent to about 1,100 school people in the state. This call was signed by Professors Bartol and Owen of Bucknell University, Prof. Scheidt of Franklin and Marshall College, Lancaster; Mr. Dysart of Pittsburgh Schools; Dr. Geo. Hull of Millersville Normal; Mr. Wallize, of Milton High School, Milton, Pa., and Jane Mathews' High School, Altoona, Pa.

There was not as large an attendance as we had hoped to have, but what the meeting lacked in numbers it made up in enthusiasm, and we hope from small beginnings greater returns.

A committee was appointed to draw up the Constitution which was submitted to those interested in the movement at a later meeting. this committee was composed of J. Mathews, Altoona, Pa.; Mr. Wallize, Milton, Pa.; Mr. J. F. Adams, Millersburg, Pa.; and Prof. Convers, Sunbury, Pa.

The following is the Constitution submitted:

1. *Name:* Science and Mathematics Section of the High School Dept. of the Pennsylvania State Teachers' Association.

2. *Object:* The improvement of the teaching of science and mathematics in Pennsylvania.

3. *Membership:* Members of the High School Dept. of the State Teachers' Association may become members upon application to the Executive Committee of the Section.

4. *Organization:* The direction of this action shall be in the hands of an Executive Committee of five members representing college, Normal school, and secondary schools.

5. This Executive Committee shall be chosen at a business meeting of the section, to be held at the time of the mid-year meeting of the High School Dept. JANE MATHEWS, *Secretary.*

ASSOCIATION OF OHIO TEACHERS OF MATHEMATICS AND SCIENCE.

The fourth annual meeting of the Association was held in Chemical Hall, Ohio State University, Columbus, Dec. 27 and 28, 1906. President W. H. Wilson, University of Wooster, presided at the joint sessions and those of the mathematics section. Vice-president T. Otto Williams, Evarts High School, Circleville, presided over the science section.

The following papers were presented:

JOINT SESSIONS.

"Arithmetic as a Means of Impressing Chemical Facts," Prof. M. E. Kleckner, Heidelberg University.

"Do Mathematical Problems Make Physics Unpopular? If so, why?" Prin. H. M. Ebert, Elyria High School.

MATHEMATICS SECTION.

"Recent Pedagogical Movements in Mathematics in Germany," Prof. Arthur G. Hall, Miami University.

"Mathematics in Ohio Colleges," Prof. G. N. Armstrong, Oberlin College.

"The Use and Abuse of Tests in Mathematics," Mr. C. J. Bowman, Canton High School.

"The College and the Teacher of Mathematics," Prof. Henry L. Coar, Marietta College.

SCIENCE SECTION.

"The Laboratory Workshop," Mr. Ralph W. Buck, Central High School, Xenia.

"Position of the Atomic Theory," Prof. Wm. Lloyd Evans, Ohio State University.

"Ions from the Physicist's Standpoint," Prof. J. A. Culler, Miami University.

"Ions from the Chemist's Standpoint," Prof. G. O. Higley, Ohio Wesleyan University.

Experiments and exhibits of home-hade apparatus were special features of the meeting. Prof. Evans performed a number of striking experiments in physical chemistry. Prof. Hillig, St. Johns College, Toledo, showed a simple experiment in electrolysis.

Mr. Buck gave a demonstration with an opaque projector and a projection microscope of his own construction. Dr. Culler of Oxford, R. O. Austin, and Miss Wilson of Columbus, also had pieces of physical apparatus on exhibition.

The following officers were elected: President, J. A. Culler, Miami University, Oxford; Vice-president, M. E. Graber, Heidelberg University, Tiffin,; Secretary-Treasurer, Ralph W. Buck, Central High School, Xenia.

M. E. GRABER, *Sec'y.*

THE AMERICAN FEDERATION OF TEACHERS OF THE MATHEMATICAL AND THE NATURAL SCIENCES.

In accordance with the call, issued by joint action of a committee of the American Society of Teachers of Mathematicvs and the Natural Sciences and one of the Central Associat on of Science and Mathematics Teachers, a meeting of delegates of a number of associations was held in New York on Dec. 27, 1906, for the purpose of discussing the formation of a federation of associations of teachers of science and mathematics. A roll of the meeting was taken, and it was found that there were present 27 delegates, representing 7 associations as follows: The Association of Mathematics Teachers of the Middle States and Maryland, 9 delegates; The New York State Science Teachers' Association (Mathematics Section), 6 delegates; The Central Association of Science and Mathematics Teachers, 5 delegates; The Association of the Teachers of Mathematics of New England, 3 delegates; The Association of the Teachers of Physics of Washington City, 2 delegates; The Missouri Society of Teachers of Mathematics and Science, 1 delegate; The New Jersey State Science Teachers' Association, 1 delegate.

Professor T. S. Fiske of the Association of Mathematics Teachers of the Middle States and Maryland was elected chairman of the meeting, and Professor C. R. Mann of the Central Association of Science and Mathematics Teachers was made secretary.

After some preliminary discussion, it was, on motion duly seconded, unanimously voted:

That it is recommended that there be formed by the various associations of teachers of science and of mathematics, an American Federation of Teachers of the Mathematical and the Natural Sciences.

The question of the form of the organization was then taken up. Two different forms were proposed; one that of a single society of teachers of mathematics and the mathematical sciences, the membership to be limited to associations that publish literature and reports; the other, a rather loose federation of all associations of teachers of either mathematics or natural sciences, the membership being limited to associations that have more than fifty members. The first of these forms was that adopted by the American Society of Teachers of Mathematics and the Natural Sciences at the conference held at Asbury Park in 1905. The latter form was proposed by the Central Association of Science and Mathematics Teachers.

In the discussion of this question, the latter form of organization was shown to be less formal and more flexible and to interfere less with the individual activities of the associations. Because this form of federation appeared to furnish the necessary basis for a first step toward a more complete organization, and because it was considered advisable that associations not represented at the meeting should have a voice in the final decision, it was, on motion duly seconded, unanimously voted:

That the form of organization proposed by the Central Association of Science and Mathematics Teachers in the printed circular issued by them be tentatively adopted for the coming year, the final form of organization to be decided at the next meeting.

No officers were elected; but an executive committee, which should look after the interests of the Federation for the next year, was elected as follows: T. S. Fiske, Columbia University, Chairman; C. R. Mann, University of Chicago, Secretary-treasurer; H. W. Tyler, Massachusetts Institute of Technology; R. E. Dodge, Teacher's College, New York; F. N. Peters, Kansas City High School.

On motion duly seconded, it was voted:

That this executive committee have power to fill vacancies and to add its membership by unanimous vote.

On motion, the meeting adjourned, subject to the call of the executive committee. C. R. MANN, *Secretary*.

BOOK REVIEWS.

Manual of Physical Geography. By C. T. Wright. 178 pages, 46 cuts with notebook paper and blank maps bound in the book. Ginn & Co., Chicago.

This is the latest one of the increasing number of laboratory manuals in physical geography. It shows the experience of a practical teacher of secondary classes. The author has made a radical departure from the style of the various current manuals by devoting fifty or more pages to definite references which closely correlate with the given laboratory exercises. The idea has been to introduce "special terms" about which are to be grouped the "truths of each lesson." The "special terms" are quite frequently insufficient in number and in some lessons have been omitted. The list of references are suitable for secondary school work and it might be strengthened by a greater use of the splendid monographs and bulletins of the United States Geological Survey, the International Geography, Hann's Climatology, Mill's Realm of Nature, Brigham's Geology and some of the standard texts in geology. In the references for Geographic Influences upon History, one misses Semple's book, which is a classic. The Origin of the Landscape by Geikie will furnish students with much material to illustrate the relation of people to land forms. Some of the Water Supply paper issued by the Geological Survey will give a better idea of artesian wells than could be obtained from the references cited. (See Water Supply paper No. 160.)

The sixty-eight exercises are well distributed among the various subjects; the land having twenty-five, atmosphere seventeen, earth as a planet eight, ocean eleven, minerals six, and two miscellaneous. The exercises on contour lines are well planned and the illustrative maps are clear and useful. The exercises are uniformly graded and very definite in purpose; occasionally one falls below the author's standard, as exercise LXII. The tendency in the past few years has been away from work similar to exercise XLIV. The last exercises are upon rocks and minerals; these would work out better if placed at the beginning of the land study along with weathering and erosion. Many of the exercises are from fresh fields in the West and will prove stimulating to teachers and pupils. Figures 14, 18, and 19 are excellent; 42 and 43 should appear nearer the text that they illustrate. The book as a whole conforms closely to the recent recommendation for work in Physiography and the teachers will find it a real aid in working with secondary classes. W. M. GREGORY.

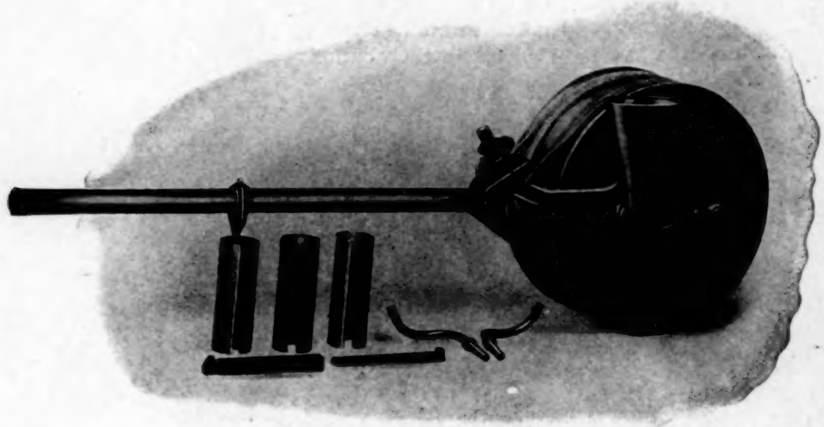
An Introduction to Astronomy. By F. R. Moulton, Ph.D., Assistant Professor of Astronomy in The University of Chicago, pp. xviii + 557, The Macmillan Co., 1906.

In a short preliminary outline the author seeks to impress upon the mind of the beginner (for it is a beginner's book) the meaning of the study of science and the general purpose of astronomical study. The very difficult task of doing this without confusing the learner with too great detail or too elaborate a philosophical disquisition is excellently achieved.

Contrary to custom with beginners' texts in astronomy, but in accord with the principles of good teaching, a chapter on the most striking facts about the constellations is then given. This serves both to impress the learner at once that astronomy really has "something to do with he stars," and gives him body of ideas to use as a basis of thought in the later study.

Then follow remarkably rational elucidations of the standard topics of descriptive astronomy, closing with a chapter, far above the customary, on Stars and Nebulae. In this chapter the author sketches the Spiral Nebular Hypothesis, called by Chamberlain, the Planetessimal Hypothesis, in a way so fair to current views and so clearly and judicially that no one need find difficulty in understanding its broad features. That the new hypothesis already co-ordinates and organizes the facts at hand better than any hypothesis, hitherto offered, not excepting the Laplacian Nebular Hypothesis is clear. That it is to rise to the dignity of a final *Theory*, in its present form, is another matter, nor is this claimed for it by its authors. It is well known that Mr. Moulton is one of the authors of this new view of cosmogony, which is rapidly gaining ground with the best thinkers in the field.

The binding and general get-up of the book are not in keeping with the contents. It is hoped the publishers may improve their part of the book in later editions. G. W. M.



PRONY BRAKE
BUILT BY INTERNATIONAL INSTRUMENT CO., CAMBRIDGE, MASS.

"MODERN PRONY BRAKES."

Prony brakes are designed for absorbing and measuring the mechanical output of small high-speed engines and motors. The modern types are the outcome of a careful thought and practical experience and afford a simple, compact and accurate method of performing such tests, as efficiency, heating and overload capacity.

The mechanism consists usually of a cast-iron box pulley provided with oiled friction ropes wrapped around the periphery and varying in number from two to a dozen as needed.

The dimensions would be, in a 10 h. p. size for example, perhaps 12" diameter and 6" face with a torque arm 30" long. The torque arm is mounted on a hub that is concentric with the pulley hub and free to rotate thereon. The friction ropes, both ends of which are conveniently made fast to this torque arm, tend to rotate it about the axis of the pulley as a centre. A pin on the arm, two feet from this centre, rests against a stop through which the pressure developed by the torque is transmitted vertically to the weighing mechanism, *i. e.*, to spring balance or platform scales.

The power thus absorbed by friction appears as heat which is dissipated by boiling away water inside the pulley. The process is smooth and quiet and the conditions of absorbtion become constant as soon as the temperature of the water has reached the boiling point. We see here an interesting illustration of the conservation and conversion of energy, beginning with electricity (or steam or gas) in the prime mover, passing to the mechanical energy of rotation against resistance, then to heat energy and finally into the evaporation of the cooling water.

The load is varied by altering the tension on the ropes and this can be adjusted to a nicety by a hand-operated screw movement. The

screw is made reversible in position to allow the tension to be applied, as may be desired, either with or against the drag of the ropes. The brake arm is also reversible to allow rotation in either direction. It may be noted that the brake is thus entirely self-contained and can be quickly mounted on or unmounted from a machine in place of the usual driving pulley. This portability makes it especially convenient for experimental testing.

The output of such a prony brake, in horse-power, is expressed by the well-known formula

$$\text{H. P.} = \frac{2 \pi N T}{33000}$$

where N is the speed in revolutions per minute and T is the torque, or turning movement, in pound-feet (pounds at one foot radius). Since the brake arm is often two feet in length, T is usually equal to twice the actual balance reading in pounds, P. Hence

$$\text{H. P.} = \frac{4 \pi N P}{33000} = .0003808 \text{ N P.}$$

Thus one dimension of the brake only enters into the calculation of the power output. The thickness of the ropes, the exact diameter of the pulley face and the actual tension on the ropes are eliminated by the method of measurement and no correction has to be applied as the ropes wear away with use. The length of torque arm, as stated, is usually two feet and means of adjusting this is provided so that it can be set acurately once for all. The friction in the journals of the torque arm does not introduce an error into the measurement since the drag due to this friction is measured as part of the load. Allowance is made for the unbalanced parts of the brake arm by taking a zero reading on the scales. Thus nothing more than speed and balance readings have to be observed for each load.

For measuring the torque a platform scale is preferably to be used so that greater acuracy in adjusting to any desired value of torque can be obtained by floating the scale beam at the time of reading. This is particularly convenient when a constant torque has to be maintained as in a heat run or a steam consumption run. The cheaper but less accurate spring balance can, however, be readily used for the torque measurement. The speed is measured with a tachometer or with a stop watch and revolution counter.

Special attention should be taken to make adequate the device for handling the cooling water of the brake. To this end the pulley is best provided with exceptionally deep flanges to prevent annoyance from spilling out of water either when the supply is being renewed during operation or when the brake is being brought to rest. The flange on the driving side is preferably solid with the hub and arranged to take the place of spokes. Water is introduced by means of a stationary funnel tube mounted on the brake arm. The inner end of this tube discharges at a point one-half inch from the inner periphery through a special nozzle. The shape of the nozzle is such that, when the depth of water in tne revolving pulley exceeds one-half inch, the surplus is forced to back up in the funnel tube, thus affording a simple indication of a sufficient water supply.